CORROSION

Vol 46 No. 2

& Materials

April 2025
In this issue:

Feature Article
Passive Realkalization for Addressing Carbonation-Induced Corrosion

Plenary Papers
Using Long-Term Performance Data for Design of Galvanic Cathodic Protection Systems

Deterioration of Concrete Piles Underwater

Case Study
Enhancing High-Rise Longevity: The Power of Cathodic Protection

FEATURE: CONCRETE STRUCTURES

THE AUSTRALASIAN CORROSION ASSOCIATION INC.

Official Publication of The Australasian Corrosion Association Inc

CORROSION

& Materials Journal

- ***Connect** with the Experts*
- ***Influence** the Industry*
- ***Reach** the Heart of the Corrosion Community*

ADVERTISE IN CORROSION & MATERIALS JOURNAL

Distributed nationally to over 3000 readers, Corrosion & Materials Journal is the mostly widely read within its market. The readership is highly targeted: senior decision makers with real purchasing power from major professional firms, universities, government, and research institutions.

WHY ADVERTISE?

- **Targeted Audience:** Tap into a niche market of dedicated professionals. Our readers are your direct audience - engaged, informed, and influential in corrosion.
- **Industry Leadership:** Position your brand alongside the leading voice in corrosion prevention and management. We don't just report on trends – we set them.
- **Quality Content:** Benefit from association with our high-calibre articles, case studies, and industry insights. Your brand will be in good company.
- **Extended Reach:** Beyond the page, your message resonates. Our journal amplifies your visibility, reaching a wide audience of professionals.
- **Engagement and Impact:** Our readers don't just skim; they engage. This means higher visibility and lasting impact for your advertisement.
- **Custom Solutions:** From full-page spreads to thought leadership pieces, we offer a range of advertising options tailored to your needs.

2025 FEATURES

- *Maritime*
- *The Water and Waste Water Sector*
- *Oil & Gas*
- *Concrete Structures*

CONTACT ROD TO BOOK NOW:
rod@glosscreativemedia.com.au or 0418 114 624

Dear ACA Members,

I was very pleased to host the ACA Board to the annual strategy day on 21st of February and the the Board meeting on the 22nd of February. We also took the opportunity to invite Austin Bennett, Chair of the Young Corrosion Group, to the strategy session to ensure we had the input from our younger leaders in the sector, as well as all the team at Head Office in Preston.

Part of the strategy session was to consider all the external impacts on the corrosion sector and also review how we have performed as an association in 2024. More of these details will be presented at our AGM in June. Some of the highlights included an increase in the training courses we delivered, an increase in membership, a successful conference in Cairns in November, and a better financial result than we budgeted for 2024.

We have reviewed our three-year strategy and refined it for 2025-2027. The key points for focus for the next three years include:

- Now we have completed consultation with Council on the PAGS (Project to Align Governance to Structure) which includes a proposed change to our constitution – the next step is to ask all members to vote on the proposed enhancements recommended by the Board and Council. For more details see: PAGS (Project to Align Governance to Structure) - The Australasian Corrosion Association Inc.
- To expand our newly revised Certification Program and integrate it into our digital systems where possible.
- To further develop our introduction to Corrosion training content for Asset Owners to allow us to provide a taster of what services our sector offers and how to build on this knowledge.
- Continue our advocacy efforts for Industrial Painters & Blasters recognition, engaging with Asset Owners, and spreading the word on Corrosion.
- To encourage our members to appoint more 'YCG' delegates onto their corporate memberships that are offered as free placements by the ACA.

In addition to these points, another operational aspect ACA is now dealing with is we have been given notice by our landlord (Melbourne Polytechnic in Preston) to vacate by the end of the year. The team are now investigating potential new premises, preferably on the North side of Melbourne. Any suggestions for premises, and training venues available through our members will be gratefully considered.

Kingsley Brown

ACA Board Chair

Feature: Concrete Structures

Reports

Profiles

Industry News

Training News

Feature: Concrete Structures

Feature

Case Studies

Member Benefits

Plenary Paper

PRESIDENT'S REPORT

Greetings Fellow Corrosionists,

Christmas and New Year has come and gone!

We are well into April of 2025, and what an exciting period it has been. Whether it is from politics, tariffs, or your anticipation of the upcoming ACA Roadshow!

As I write this letter, I am getting ready to attend the AMPP Annual Conference and Expo, that is being held in Nashville, Tennessee. This is my first time attending this event, and I look forward to representing the ACA, alongside our Board Chair, Kingsley Brown and our ACA CEO, Maree Tetlow as well as reporting back to you on the latest developments relating to our industry.

A few days ago, we held our first ACA Council meeting for the year, where we received an operational update from our CEO, which shows that we are starting the year with a healthy financial balance, a number of technical and training events for us to look forward to, and preparation for our own annual conference well underway. This was followed by our Board Chair, who gave us an update on the proposed update of our constitution, with the aim to strengthen our organization for the foreseeable future.

As always when you have a (virtual) room of passionate people, the Councillors had a couple of robust discussions, all of which was focusing on how we can evolve in an ever-changing world, maximise the membership benefits, grow our numbers, especially with young corrosionists, in addition to other matters.

Speaking of growing and evolving, we are looking for a Junior Vice President, so if you are interested in expanding your horizons and trying something new, feel free to get in touch.

I would also encourage you to consider joining your local Branch Committee, after which, you can be nominated onto the Council, and even the Board, if you choose to.

Either way, feel free to get in touch with me directly, my (virtual) door is always open for a chat.

Raed El Sarraf

ACA President.

Dear ACA Members

The first quarter of the year has whizzed by, and the ACA Team have been busy.

We have welcomed two new members to the team. Adrian Ruggiero is our new General Manager Operations. Adrian has extensive senior executive experience in organisational leadership, high-performance team development and project management in Not-for-Profit organisations, the energy sector, construction, property services and mobile telecommunications industries. Adrian will be supporting the team to deliver a higher level of service, manage our digital projects, and provide additional structure for the operations team, as well as act as my 2IC. With Adrian commencing at ACA in January, I am now spending more time working remotely from Tasmania.

The second new member of our team replaces Greg Carter, our part-time Company Secretary who retired at the end of December 2024. Conference delegates may have met Greg at the C&P Conference in Cairns and previously in Perth. Geraldine Allen is our new Company Secretary, and she works typically on a Wednesday. Geraldine is a CPA and governance professional with a hands-on financial management background.

Welcome to both Adrian and Geraldine!

Other matters to report are that we have updated our rolling Strategy with the ACA Board in February and provided the draft to the ACA Council for feedback.

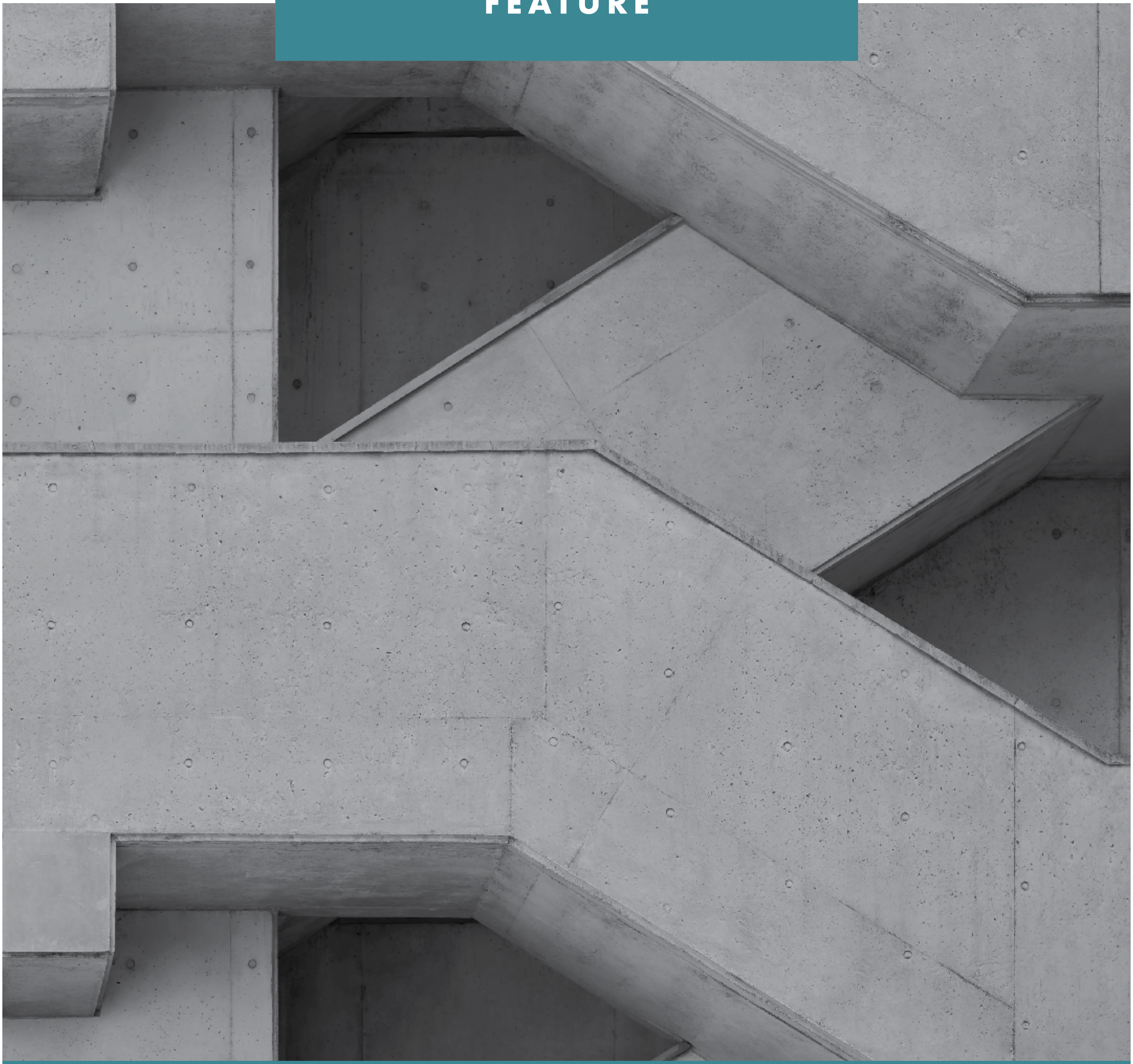
I am also pleased to advise members that 2024 was a strong year for the ACA and we delivered a healthy surplus that is now under review by our auditors. We delivered more training and membership services than in previous years, and details of all our KPI's and financial performance will be reported to members at the June AGM.

Thank you to everyone that has completed or intends to complete our member satisfaction survey. It is important for the ACA to continue to improve our services, understand members' challenges and priorities so we can refine our plans, and the team can reflect on our performance over the past couple of years.

Finally, I am off to the AMPP Conference in Nashville in April. I will be accompanied by ACA Board Chair, Kingsley Brown. The main agenda for the ACA at the conference is to meet up with the education team, discuss next steps regarding our ongoing NAVSEA requirements in Australasia, and represent Australia at international forums. If you have any feedback, get in touch at maree.tetlow@corrosion.com.au All the best!

Maree Tetlow

ACA CEO



Seeing the Unseen: Data and Inspection in Corrosion Prevention

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

In my previous articles on corrosion management (refer to ACA Materials and Corrosion Journal July 2024 & January 2025), I introduced the essential elements of a robust management program and explored the critical roles of Policy and Leadership and Planning and Procedures. Now, I will delve into two more crucial elements: Data Gathering and Analysis and Inspection and Monitoring. These components are fundamental in understanding corrosion behaviour, predicting failures, and implementing proactive mitigation strategies.

Data Gathering and Analysis: Building the Foundation for Corrosion Management

Data serves as the backbone of any effective corrosion management strategy. The ability to collect, store, and analyse relevant data enables organizations to make informed decisions about asset integrity, maintenance scheduling, and risk mitigation.

Key Aspects of Data Gathering and Analysis

1. Material and Environmental Data Collection

- Understanding the properties of materials used in infrastructure and their susceptibility to corrosion in specific environments is critical.
- Collecting environmental data such as humidity, temperature, pH levels, and exposure to corrosive agents helps in predicting corrosion rates.

2. Operational Data and Corrosion History

- Gathering historical corrosion data, including previous inspection reports, failure records, and maintenance logs, provides insights into degradation patterns.
- Operational parameters such as pressure, flow rates, and chemical exposure contribute to corrosion analysis.

3. Data Management and Analysis Tools

- Modern data analysis software enables real-time monitoring, pattern recognition, and predictive analytics.
- Implementing machine learning algorithms and big data analytics enhances corrosion prediction and optimizes asset maintenance strategies.

4. Corrosion Rate Calculations and Predictive Modelling

- Using standardized formulas and industry models, engineers can estimate corrosion rates and assess the remaining lifespan of assets.
- Simulation tools help in forecasting corrosion behaviour under various operating conditions.

Case Study: Optimizing Corrosion Monitoring in Piping Systems

A case study conducted by Pinnacle Reliability (Reference 1) addressed corrosion-related challenges in an industrial setting by optimizing Condition Monitoring Locations (CMLs) within piping systems. Initially, the facility had a blanket placement of 7,912 CMLs, all utilizing spot ultrasonic testing (UT) techniques, which created many cost and process inefficiencies for the inspection program.

Approach:

- A thorough corrosion study was conducted to identify high-risk areas within the piping network.
- The existing 7,912 CMLs were optimized down to 1,680, achieving a 78.8% reduction.
- Additionally, 446 new CMLs were introduced to monitor previously under-inspected high-risk locations.

Outcomes:

- The optimized CML placement allowed for more effective corrosion monitoring.
- The reduction in CMLs led to more efficient use of inspection resources.
- Improved understanding of corrosion risks enhanced asset reliability and longevity.

This case underscores the significance of data-driven analysis in refining inspection strategies to manage corrosion effectively.

Inspection and Monitoring: The Frontline Defence Against Corrosion

Regular inspection and continuous monitoring are vital in detecting corrosion-related deterioration before it leads to catastrophic failures. These activities provide the necessary feedback to refine corrosion control strategies and improve risk management.

Key Inspection and Monitoring Techniques

1. Visual Inspections
   - One of the simplest yet effective methods, visual inspections help identify surface-level corrosion, coating failures, and early signs of material degradation.
   - Digital imaging and drones are increasingly used for remote and hard-to-reach areas.
2. Non-Destructive Testing (NDT) Methods
   - Ultrasonic Testing (UT): Measures wall thickness and detects internal corrosion without damaging the structure.
   - Radiographic Testing (RT): Uses X-rays or gamma rays to inspect internal flaws in welds and metal components.
   - Magnetic Particle Testing (MPT): Detects surface and near-surface cracks in ferromagnetic materials.
   - Eddy Current Testing (ECT): Detects surface and near-surface cracks in conductive materials. .
3. Electrochemical and Sensor-Based Monitoring
   - Corrosion Coupons: Small metal samples exposed to the environment, periodically analysed for corrosion rates.
   - Electrical Resistance (ER) Probes: Measure material loss over time.
   - Electrochemical Impedance Spectroscopy (EIS): Provides insights into corrosion mechanisms at a micro level.
   - Real-Time Corrosion Sensors: Advanced IoT-enabled sensors provide continuous monitoring and data transmission.
4. Remote Monitoring and Data Integration
   - Wireless sensor networks and cloud-based data integration enable real-time tracking of corrosion parameters.
   - Digital twins and predictive analytics enhance maintenance planning and risk assessment.

Case Study: Addressing Corrosion in a Crude Distillation Column

Preem's Lysekil refinery in Sweden faced severe corrosion at the top of its main crude distillation column, particularly near a complex arrangement of pressure relief valves. Despite initial mitigation efforts, corrosion reoccurred after approximately five weeks (Reference 2).

Approach:

1. Focused inspections identified specific areas affected by corrosion, allowing for precise intervention planning.
2. Continuous monitoring and analysis of corrosion data helped understand the underlying causes and progression.

Outcomes:

- Data-driven insights enabled informed decision-making regarding maintenance and mitigation strategies.
- Continuous inspection and monitoring ensured adaptation to evolving corrosion challenges.

This case highlights the critical role of ongoing inspection and data analysis in identifying and addressing persistent corrosion issues in complex industrial systems.

The Synergy Between Data Analysis and Inspection

Combining data gathering and analysis with inspection and monitoring creates a feedback loop that strengthens corrosion management programs:

- Inspection results validate predictive models, improving accuracy.
- Data analysis helps prioritize inspection schedules, focusing on high-risk areas.
- Continuous monitoring ensures that corrosion control measures are effective and adjusted as needed.

Conclusion

A robust corrosion management program must incorporate Data Gathering and Analysis and Inspection and Monitoring as integral components. By leveraging advanced data analytics, predictive modelling, and modern inspection techniques, organizations can proactively manage corrosion risks, enhance asset integrity, and optimize maintenance strategies. The case studies demonstrate how real-world applications of these elements drive efficiency and safety. In the next article, I will discuss Risk Assessment and Mitigation and Repair, further strengthening the foundation for effective corrosion control.

References:

1. https://pinnaclereliability.com/learn/case-studies/case-study-overcoming-corrosion-related-challenges-through-condition-monitoring-location-optimization/
2. https://www.emerson.com/documents/automation/case-study-preem-lysekil-achieves-success-corrosion-erosion-en-9238658.pdf

About the Author:

Mr. Dehghan is a Chartered Professional Engineer. He is a Mechanical Integrity Specialist with over 17 years of expertise in on/offshore oil & gas and petrochemical sectors.

ANNOUNCEMENT

C&P25 MATERIALS PROTECTION FOR THE FUTURE PPG

PLENARY SPEAKERS

Submission of abstracts of technical papers and case studies has closed with 116 abstracts being received on a wide range of corrosion mitigation topics including;

- **ASSET MANAGEMENT (23)**
- **CATHODIC PROTECTION (18)**
- **COATINGS (16)**
- **CONCRETE (13)**

Other topics well represented are sustainability, MIC, CUI, and marine.

Passive Realkalization for Addressing Carbonation-Induced Corrosion

Paul Mukhin
Business Development Officer at Alkyon.

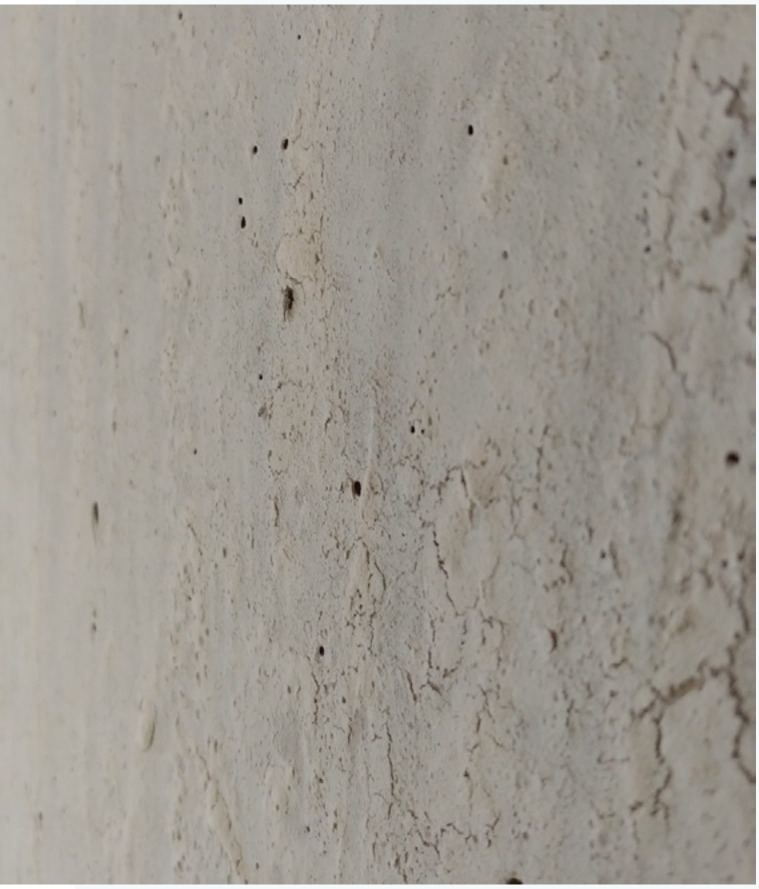


Figure 1: Dried residues of a Penkal Realkalization Solution application undertaken to a carbonated concrete wall prior to its washing off.

ABSTRACT

Realkalization has long been considered a well-documented and effective method for inhibiting carbonation-induced corrosion of reinforced concrete. However, the predominant electrochemical realkalization method has seen limited uptake in Australia, attributed to its comparatively high cost and complexity in application.

An alternative method, known as passive realkalization, offers to achieve realkalization with significantly lower cost and complexity, thus allowing greater accessibility of this as a remediation method.

However, the understanding of the passive realkalization methodology is limited, and few field-viable formulations have been successfully developed, tested, and commercially offered.

We present an overview of the methodology, the performance requirements for a passive realkalization solution, along with a case study of a field-viable and commercially available passive realkalization solution.

INTRODUCTION

Carbonation-induced corrosion of concrete is one of the leading causes of failure of concrete assets, with all steel-reinforced concrete structures susceptible to this means of deterioration.

While the initial conditions formed by hydrated cement allows for steel reinforcement in concrete to be protected from corrosion, these conditions change over time through the reaction of concrete with atmospheric CO_2. These chemical changes cause the concrete to lose a highly alkaline internal environment, from which the steel to begin undergoing corrosion and progressing until either remediation is undertaken or the structure fails.

Realkalization is a remediation method which works by restoring high alkalinity in carbonated concrete. With a high pH, the steel instead forms a protective layer, thus inhibiting corrosion.

The method has traditionally been undertaken through the electrochemical method, practiced internationally and additionally used for chloride removal, though requiring greater complexity in application and thus higher costs.

However, there also exists the passive method of realkalization, using a simpler application method which offer lower costs and more accessibility to its use. Few solutions have been able to utilize the passive methodology owing to the challenges in developing a well-performing formulation and limited knowledge on the topic, though recent work in Australia have seen one particular solution rise in prominence. [1]

Within this paper, we'll first provide an overview of the theory of carbonation-induced corrosion of steel reinforcement within concrete. Following this, we'll discuss the theory behind realkalization, and the differentiation between the passive and electrochemical realkalization methods. Thirdly, we'll offer the basic performance criteria that a passive realkalization solution must demonstrate. Lastly, a case study of a commercially available solution is undertaken which highlights how it achieves the performance criteria, along with a typical application.

This diagram models the formation of various oxide species of iron in water and the role that pH and potential play in determining this. Through the manipulation of pH by realkalization, the formation of non-corrosive oxides can be favoured.[5]

The Theory of Carbonation-Induced Corrosion

With carbonation-induced corrosion, a reaction between atmospheric CO_2 and concrete results in the loss of high internal alkalinity necessary to prevent steel from corroding and the structure then failing. Without intervention and remediation, this is an inevitable fate of all steel-reinforced concrete structures.

This initial high pH within concrete is provided primarily by calcium hydroxide in the cement, along with additional alkali compounds. Within these conditions, pH is between 11 and 13.

Over time, a natural reaction between atmospheric CO_2 and the cementitious matrix results in the conversion of highly alkaline calcium hydroxide to mildly alkaline calcium carbonate, leading to a fall in pH to approximately 8.

$$Ca(OH)_2 + CO_2 \Rightarrow CaCO_3 + H_2O$$

Carbonation progresses gradually into concrete starting from the surface, forming a 'front' which

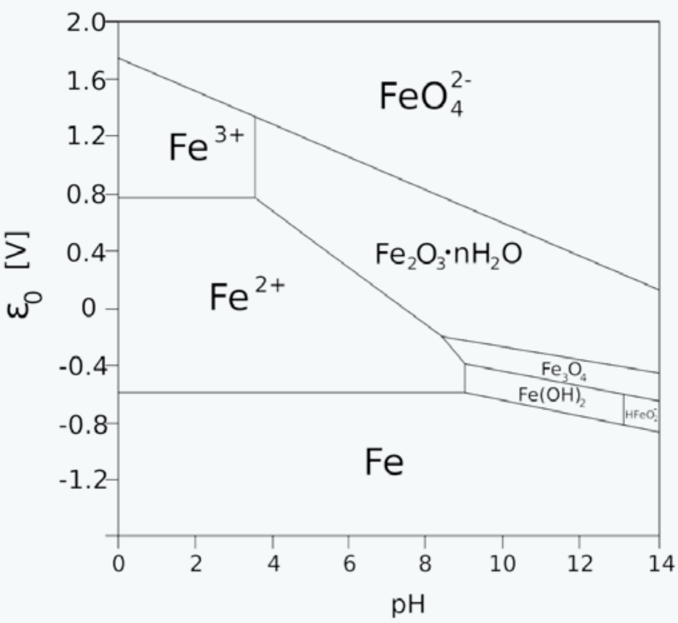


Figure 2: A Potential-pH (or Pourbaix) Diagram for Fe-H_2O at 25°C, c(Fe) = 10^{-6} M.

progresses deeper into concrete at a slowing rate.

The pH of the pore solution determines the oxide product formed on the steel reinforcement, and whether the steel is passive and effectively protected, or whether expansive corrosion progresses.

Under passivation, the steel forms effectively non-expansive oxide products on its surface, understood to be 5 to 13 microns in size, at a rate as low as 1mm per 1000 years. This is generally understood to require a pH greater than 10 for typical rebar.

However, as pH falls to 8 from carbonation, expansive corrosive products will form, resulting in the rapidly progressing deterioration of the steel reinforcement and structure. [2][3][4]

Realkalization

If carbonation lowers the pH within concrete, then realkalization restores this so that the passivity of the steel is maintained. Through restoring an alkalinity above pH 10, the oxides formed would instead be passive species, rather than the corrosive ones (Figure 2). [6]

Traditionally, realkalization has been associated with the electrochemical realkalization method, an approach involving the transportation and formation of alkaline environment with electrochemical transport system. While well standardized and long practiced, its adoption is limited by its comparatively high cost and complexity of installation. However, the electrochemical method is not the only method of realkalization.

Alongside this is passive realkalization, which achieves the increase in alkalinity using passive transportation mechanisms. In practice, it's as simple as spraying a coating onto concrete, meaning that cost and complexity could be as low as with anti-carbonation coatings.

While this method offers great advantages, the development and commercialization of a solution is technically challenging, and so few to no solutions have ever demonstrated effective performance despite decades of attempts. [4][7]

No Longer Theory

Despite the challenges, this method is no longer merely theory, but instead field-viable and commercially available.

In the previous decade in Australia, there has been one notable solution which has demonstrated its effectiveness as a passive realkalization solution in field conditions, being Penkal Realkalization Solution by Alkyon (hereon after referred to as the solution).

This solution has managed to restore high alkalinity through the carbonation front of multiple structures in the field and achieve the basic performance metrics necessary for a passive realkalization to be effective.

The solution was initially trialled in a Transport for NSW investigation into passive realkalization solutions, in which it performed successfully across all field sites. Following these trials and publication of results, it was made commercially available by the company as a specialized application service. [1]

Performance Metrics

To be an effective passive realkalization solution, it generally needs to achieve:

1. Penetration to carbonation front depth.
2. Restoration of sufficient alkalinity through carbonated concrete.
3. Durability of the restored alkalinity in the structure.

For each of these metrics, the solution has consistently demonstrated effectiveness, with the explanations and references below.

Penetration to Carbonation Front Depth

The solution has been able to consistently migrate to the depth of carbonation, with carbonation depths ranging from 20m to >50mm[1].

We determine this through pH measurement of carbonated concrete core samples acquired following applications and tested by pH indicator spray testing and ground sample quantification methods. [1]

1 Internal data, available on request

In discussing penetration depths, we must understand that penetration depths of any materials into concrete are always variable and dependent on a range of factors. One major factor is that of the porosity of concrete. A poor-quality concrete may be highly porous and demonstrate penetration depths to >100mm, while an ultra-high-performance concrete may show the same material penetration to <10mm.

As such, the statement of any material migrating to a specified depth may be considered useless without a control reference.

Thankfully, many old structures have a very useful reference, which is the depth of carbonation. Carbonation depths also depend upon many of the same factors that will influence penetration depths of material. Further, carbonation depth

(Above) Figure 3: Cross-section of concrete sample treated with the Realkalization Solution on top section following accelerated carbonation testing for 8 weeks. Light colouration indicates carbonated concrete which maintains high alkalinity (measured as pH 11.4 by ground sample leeching method), while darker areas indicate non-carbonated concrete.

(Below): Figure 4: Core samples obtained following Realkalization Solution application to a concrete slab recording carbonation depths of >45mm to fully carbonated following shortened 1 month treatment time before coring. Indicator colour change from 60mm to fully realkalized core samples.

generally proceeds at a slowing rate over time (likely accelerating once reinforcement is reached and corrosion commences).

As such, for realkalization solutions, a useful metric to determine penetration depth is migration to the carbonation front depth across multiple field sites in 'old' structures. Penkal has regularly demonstrated penetration to the carbonation depth as determined by increase in pH, including against alternative marketed solutions which failed to achieve this. [1]

Reinstatement of High Alkalinity

The solution has demonstrated reinstatement of high alkalinity, as determined by pH indicator spray testing and quantified ground sample pH testing. A minimum of pH 10 is required, with the solution generally demonstrating ~pH 11 being restored. [1][8]

Long Term Durability

The solution has previously demonstrated maintenance of high alkalinity within a 10 year old field application, with measured pH being ~10.5 and no low-alkalinity carbonation front progressing beyond the realkalized area.[8] Further, accelerated carbonation testing has shown high alkalinity (pH >11) maintained following 8 week exposure at 2% CO_2, 65% humidity (Figure 3).

Durability is heavily dependent upon formulation, with some studied materials suggesting losses of realkalization effect after several years. [2]

Thus, having achieved 3 major performance criteria to be effective as a realkalization solution in field applications, the solution can be said to be a field-viable passive realkalization solution.

Case Study

To provide an overview of the solution's application methods, we present an application undertaken to a concrete culvert in the Sydney region which is typical of the majority of applications undertaken.

Background

This structure required several remediation works, including a durability enhancement to address the risk of further carbonation-induced corrosion of the reinforced concrete. Passive realkalization using the solution was specified for this.

Carbonation depths were found to be 30 - 35mm, and concrete cover to reinforcement between 20 - 50mm. Cracks required patching, along with limited corrosion leaking in some joints.

Application

Application is typically done by spraying, brushing, or trowelling, depending on the area nominated for treatment. In this instance, application by spraying was undertaken.

The solution requires 2 coatings of formulations to be applied, typically spaced 7 days apart. After each application, the majority of the formulation would migrate into the concrete, leaving an optionally washable residue remaining (Figure 1).

In this case, the 2 applications were spaced 2 weeks apart to accommodate other scheduled works in the surrounding area, with washing of the residues undertaken 4 days after application.

Migration and Testing

After the final coating application and with the material penetrated into the concrete, it diffuses throughout the carbonation front at a slowing rate, and at 2 months following final application core samples are obtained to verify the applications effectiveness and for company warranty purposes.

Verification is typically done by phenolphthalein indicator testing on a cross-section of a concrete core sample obtained from the structure. This is effectively the same method that's used for regular carbonation testing of concrete samples. Other pore solution pH testing methods can often be used.

Results

In this case study, our verification indicated that this passive realkalization was successful in penetrating through the carbonation front based on phenolphthalein indicator testing of acquired core samples, with no low-alkaline carbonation front observed remaining (Figure 4).

References

[1] Khatri, R., Madrio, H., Mukhin, V. (2019). Passive re-alkalisation of carbonated concrete to prolong the life of existing structures [Paper presentation]. Concrete 2019, Sydney, Australia.

[2] Glawe, C., & Raupach, M. (2024). Review of basics and new opportunities for the chemical realkalization of carbonated concrete including the application of alkali-activated materials. Magazine of Concrete Research, 1–33. doi:10.1680/jmacr.24.00026

[3] Green, W. K. (2020). Steel reinforcement corrosion in concrete – an overview of some fundamentals. Corrosion Engineering, Science and Technology, 55(4), 289–302. doi:10.1080/1478422x.2020.1746039

[4] Mietz, J. (1995). Electrochemical realkalisation for rehabilitation of reinforced concrete structures. Materials and Corrosion/Werkstoffe Und Korrosion, 46(9), 527–533. doi:10.1002/maco.19950460904

[5] Andel Früh (2006), Pourbaix Diagram of Iron. Wikimedia. https://commons.wikimedia.org/wiki/File:Pourbaix_Diagram_of_Iron.svg. CC BY-SA 2.5

[6] Huet, B., L'Hostis, V., Miserque, F., & Idrissi, H. (2005). Electrochemical behavior of mild steel in concrete: Influence of pH and carbonate content of concrete pore solution. Electrochimica Acta, 51(1), 172–180. doi:10.1016/j.electacta.2005.04.014

[7] European Committee for Standardization. (2008). EN 1504-9: Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 9: General principles for the use of products and systems (EN 1504-9). Brussels: CEN.

[8] Mukhin, P. (2024). Long-Term Durability of Passive Realkalization Solution in Concrete Remediation: A 10-Year Old Field Study [Paper ACA2024-21669]. Corrosion & Prevention 2024, Cairns, Australia.

Author Details

Paul Mukhin is the corresponding author of this paper. He is a Business Development Officer at Alkyon Pty Ltd. In this role, he works to commercialize the new remedial solutions the company develops, as well as identify new opportunities. His background is from the sciences, also works on international environmental governance, and is academically focussing on industrial ecology and the study of human society's material demands.

Within the ACA, he's Chair of the NSW Young Corrosion Group Subcommittee, and supports the Concrete Structures & Building Technical Group.

Using Long-Term Performance Data for Design of Galvanic Cathodic Protection Systems

David Whitmore[1*], David Simpson[2] & George Sergi[3]
[1]Vector Corrosion Technologies Ltd., Winnipeg, Manitoba, R3Y 1G4, Canada
[2]Vector Corrosion Technologies Ltd., Cradley Heath, B64 5HX, United Kingdom
[3]Vector Corrosion Technologies Ltd., Cradley Heath, B64 5HX, United Kingdom
[*]DavidW@Vector-Corrosion.com

Keywords:

Galvanic anodes, Cathodic Protection, Corrosion control, Steel reinforcement

Abstract:

Galvanic anodes have been used to provide various levels of corrosion protection to reinforced concrete structures for many years. Some installations have met expectations and others have not performed as desired. Failures have been associated with lack of understanding of the performance of anodes with time. Long-term monitoring of galvanic anodes has allowed detailed analysis of their performance and aided in the understanding of the way performance diminishes with time and how temperature affects current delivery. The aging effect of the anode is described by an Aging Factor which was found to be specific to each anode type. Knowledge of the Aging Factor and the mean annual temperature has permitted performance expectations and duration of protection to be defined prior to final design. Successful designs are designs which meet the specified performance expectations for the design service life and are based on the actual performance of the specified galvanic anode in the service environment. The temperature and corrosivity of the environment must be considered. Long-term galvanic anode performance data has been used to validate the proposed design approach.

INTRODUCTION

Corrosion of reinforcing steel in concrete is the leading cause of deterioration of concrete infrastructure in the U.S and worldwide [1]. Reinforced concrete structures can be designed and maintained to achieve long service lives but unfortunately, some bridges, piers, and other structures show signs of active corrosion such as rust staining and concrete spalling, during their intended service life. Left unchecked, chloride induced corrosion can lead to major structural problems. Many severely corroded structures have been replaced at great expense and with significant disruption to the public.

Galvanic anodes have been shown to control reinforcement corrosion for periods beyond 20 years, but their longterm performance behavior was not documented until recent analysis of long-term monitoring results of some early field trials [1, 2]. Careful analysis of long-term performance data and analysis of anodes removed from structures has established a mechanism of anode aging that can be predicted. A term defined as an Aging-Factor was found to allow reasonable prediction of the long-term behavior of the anodes. The Aging-Factor describes how current output diminishes with time in such a way as to be halved at constant time intervals.

This was shown by analysis of many sets of monitored galvanic anode performance data which revealed this repeated behavior of a slowly decreasing current output consistent with Equation 1 [3].

$$i_t = i_0 e^{-\lambda t} \qquad \text{Eq. (1)}$$

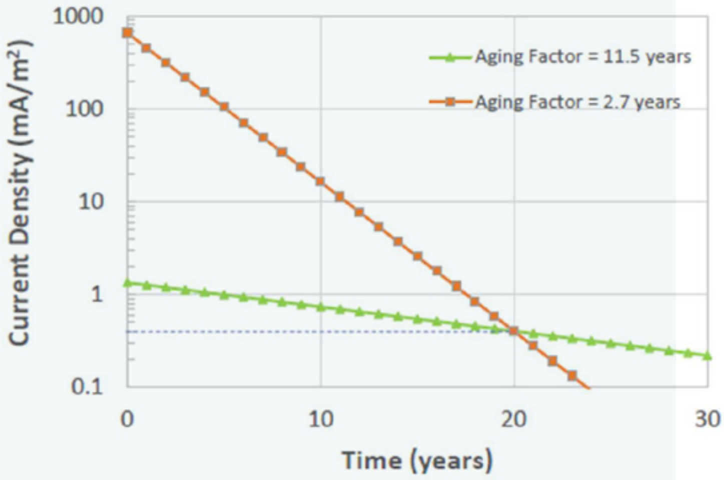
Where,

i_t = ***current density at time, t (mA/m²)***
i_o = ***initial current density, (mA/m²)***
λ = ***exponential decay constant,***
t = ***time (years)***

An Aging-Factor of 10 years describes an anode (or an anode system) whose current output is halved every 10 years.

A higher Aging-Factor describes an anode (or anode system) whose current output decreases more slowly with time. Figure 1 demonstrates this graphically for two different anode systems, one that has a higher initial current output and a lower Aging Factor, compared to an anode system with a lower initial current output and a higher Aging Factor. The figure shows that a much higher initial anode output may be required to provide a specified life if the Aging Factor is less and the current output drops more quickly.

Figure 1: Current density vs time for two hypothetical



anode systems with different initial current density outputs and aging-factors such that both anodes provide a minimum current density of 0.4 Ma/m² over a 20 year service life.

Temperature of the concrete was also shown to affect anode performance according to the Arrhenius relationship (eq. 2) where current output approximately doubles with every 10-15 °C increase in temperature throughout the typical ambient service temperature range [2]. Site data has shown the Arrhenius relationship to hold over the range of ambient temperatures (Fig. 2). The Aging Factor and the effect of temperature on current output allows a long-term design to be performed to meet a specified minimum required current output over the desired service life, such as 20 years as illustrated in Figure 1.

$$k = Ae^{-\frac{Ea}{RT}} \qquad \text{Eq. (2)}$$

Where,

k = Rate constant
A = Frequency factor
Ea = Activation energy
R = Universal gas constant
T = Temperature

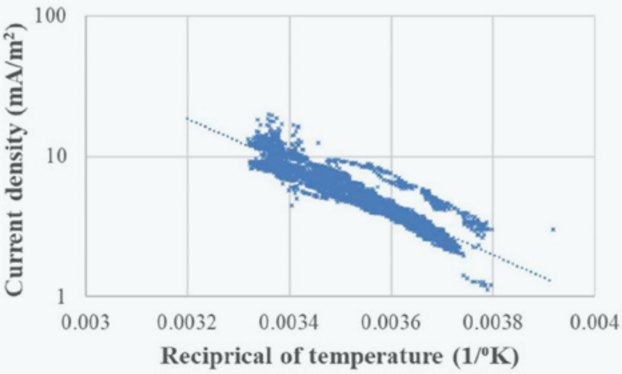


Figure 2: Variation of current output of galvanic anodes with concrete tempurature in a bridge abutment, Ohio, USA.

Design for Anodes Placed in Concrete Repairs

As the following is a proposed design procedure for anodes placed in a standard concrete repair for which cathodic prevention of the parent steel is desired up to a distance of 100 mm outside the repair. To aid in the design, a model was developed in which the anodes would deliver a current output that would be equivalent to a minimum current density to reinforcing steel positioned 100 mm outside the repair. The design current density can be varied between 0.4-1.6 mA/m^2 depending on the corrosion risk conditions for the steel reinforcement as illustrated in Table 1.

Table 1: Risk Categorization.

% Chloride (by mass of cement)	Risk Level	Current Density (mA/m^2)
<0.8	Low to Moderate	0.4
0.8-1.5	High	0.8
>1.5	Extremely High	1.6

The increase in corrosion risk as a function of increased levels of chloride in the vicinity of the steel, is consistent with Concrete Society TR73 [4] and BRE Digest 444 [5] as illustrated in Fig. 3. The doubling of the current requirement for every step increase in corrosion risk is shown in Table 1.

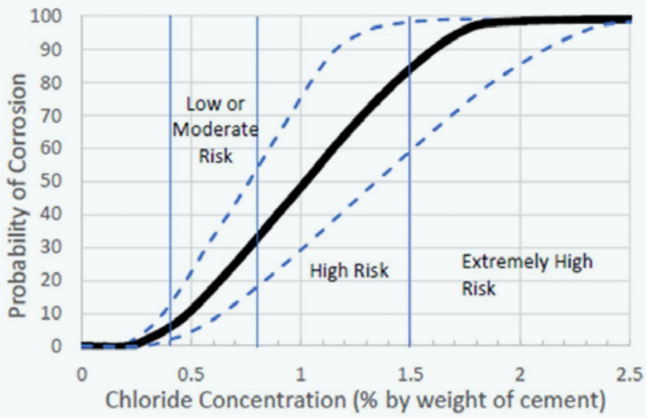


Figure 3: Corrosion risk categorization for steel reinforcement in concrete. (Concrete society tr 73, 2011, bre Digest 444 part-2, 2000)

Justification for these levels of current density is provided by Bertolini et. al [6]. In their work, current densities between 0.4 mA/m^2 and 0.8 mA/m^2 were shown to increase the threshold for corrosion initiation of steel in concrete to about 1.5% Cl- by mass of cement when chlorides penetrate the concrete from an external source. This would suggest that at levels below 1.5% Cl-, corrosion can be prevented if the current density is 0.8 mA/m^2 or higher. It was further shown that 1.6-1.7 mA/m^2 prevented corrosion initiation even if 3% Cl- had accumulated around the steel. Furthermore, results from Leicester, UK [1], showed that corrosion did not initiate when a current density of at least 0.4 mA/m^2 was maintained at moderate chloride levels but initiated when it dropped to approximately 0.3 mA/m^2 at around Year-15.

In the following example, the model assumes the in-situ resistivity of the parent concrete to be 15-

25 kΩ.cm and allows the concrete repair material resistivity to be up to 50 kΩ.cm. The model also considers the current delivered by adjacent anodes to the steel in question which in this example is 100 mm outside the repair. If the concrete resistivity is outside the limits suggested above, the model needs to be adjusted accordingly.

The mean initial early current output for a high output anode at a standard temperature of 10°C is known from trials to be approximately 465 μA. The current at Year-20 for an Aging Factor of 12.5 would thus be 165 μA (Fig. 4).

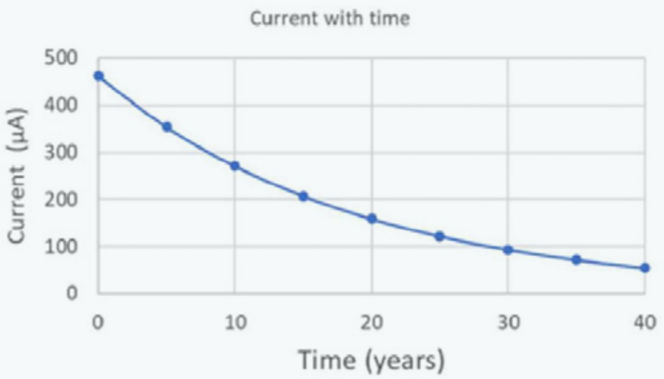


Figure 4: Expected current reduction of the anode with time up to 40 years assuming an aging factor of 12.5 years.

The expected zinc mass consumed over the 20-year period is determined by the charge delivered by the anode using Faraday's Law, assuming an efficiency of 75% [1,7] and calculates as approximately 84 g. The mass of zinc in the high output anode evaluated in this study is about 132 g. The additional mass is required to deal with cases where current output is higher such as when the annual mean temperature approaches and exceeds 15°C as well as to ensure that enough surface area remains for the current output to be sufficient in later years.

The spacing to achieve the current density required for any risk level and steel density at Year-20 for the appropriate level of risk is calculated using the above-mentioned model and plotted as a set of graphs of Anode Spacing versus Steel Density for ease of use (Fig. 5).

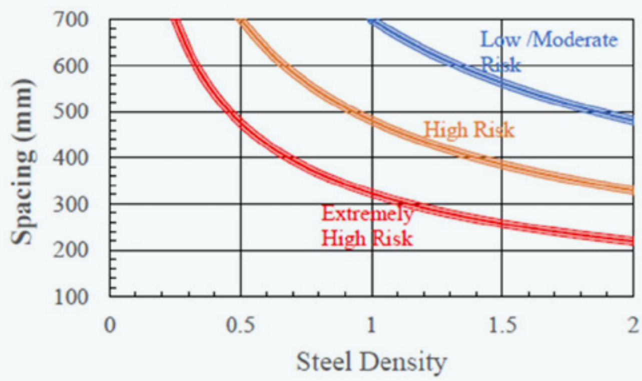


Figure 5: Spacing for three levels of risk, as detailed in figure 3 and table 1, in relation to steel density (ratio of surface area of steel to concrete surface area) for the high output anodes considered in the model.

A rough approximation of the required spacing can be estimated by calculating the mean current density to a square area around a single anode with dimensions equal to the required spacing and the corresponding steel area within the same area. This should give around the same value as the required current density with an error of approximately ±25%. This estimation is only useful as a check and not as an alternative for calculating spacing.

For a steel density of 0.9, i.e. the area of steel surface (in m^2) contained within 1 m^2 of concrete surface area, the anode spacing determined from Figure 4 for a high-risk environment is approximately 500 mm. Anodes would thus be positioned at a maximum spacing of 500mm on center around the perimeter of the repair to achieve a minimum current density at a location 100 mm into the parent concrete of 0.8 mA/m^2. In the first few months after connection of the anodes to the steel, the current density is thus expected to be 2.25 mA/m^2 and will decrease overtime as illustrated in Figure 1 and Figure 3. As mentioned earlier and indicated in Table 1, the aim of the design is to achieve the mean current density for corrosion prevention of 0.8 mA/m^2 at year 20.

High Temperature Environments

Anodes deliver a higher current in warmer climates which means that their expected life will be reduced and they may not deliver the required current density at 20 years unless temperature is taken into account during the design process. Higher mass anodes which have the same initial surface area are available to provide longer service life in high temperature environments. The assumption in this case is that the higher mean exposure temperature causes a doubling of the current output of the anodes (e.g., at a mean annual temperature of 25°C as opposed to 10°C). Corrosion levels also follow the Arrhenius relationship so they too would be approximately double, so the additional current delivered by the anodes is required to prevent corrosion initiation in higher temperature environments. Furthermore, if the anodes are exposed at these substantially increased temperatures, such as anodes installed in a tropical environment, the zinc consumption of the high output anode used in the above calculations is expected to at least double to 168 g at 20 years. Extra anode mass is required to satisfy the higher current output which will occur. The same surface area of the anode should remain since the current output would otherwise increase substantially and service life would be compromised. Proper surface area to volume of the metallic component of the anode is critical to achieve the correct balance of current delivery and service life.

The same graph as in Figure 4 is still applicable for these larger zinc mass anodes as a doubling of the applied current would be required to achieve the same protective effect. If the mean annual temperature is expected to exceed 20°C, larger mass anodes should be used. Spacing calculations remain the same irrespective of temperature.

Design for Distributed Anodes Placed in Concrete Encasements and Overlays for Corrosion Control

For Corrosion Control, the use of a second approach based on the application of the minimum current density delivered to steel at the furthest point between two adjacent distributed anodes (DAS) is recommended. Table 2 below gives the recommended minimum current density for corrosion control for a range chloride concentrations / corrosion risk levels.

Table 2: Risk categorization for corrosion control

% Chloride (by mass of cement)	Risk Level	Current Density (mA/m²)
<0.8	Low to Moderate	0.6
0.8-1.5	High	1.2
>1.5	Extremely High	2.4

The recommended anode spacing will vary with the steel density, the chloride concentration in the vicinity of the steel and the desired service life. Since the current output from a galvanic anode diminishes over time, the recommended spacing between anodes will reduce when the design service life is increased. It is important to use the actual field performance vs time curves for the specific anode to be used to make sure the current output does not drop below the desired design current density before the end of the design service life.

Figure 6 shows a series of curves for a design example where a structure has 1% chloride by weight of cement and DAS X anodes are used to provide a minimum current density of 1.2 mA/m^2 at the end of the design life. Spacings for three different service lives, 10, 20 and 30 years are shown. If a 30-year service is required and the steel density of 0.9, a maximum spacing of 400 mm is recommended to achieve the minimum required current density at 30 years.

Figure 7 shows how the current output from the anodes decreases over time as well as how current output changes if the average annual temperature is increased or decreased by 10°C.

The consumption of zinc vs time for the example described above is shown in Figure 8.

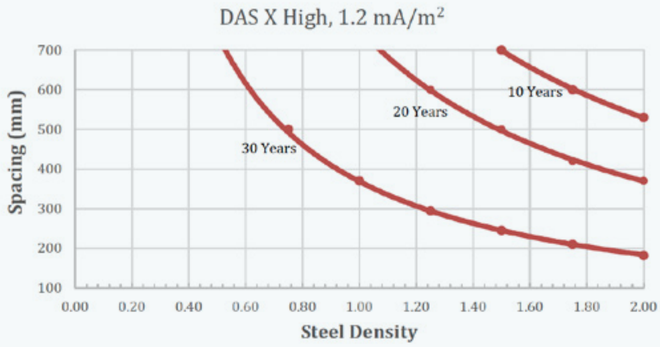


Figure 6: Spacing for three design periods in relation to steel density (ratio of surface area of steel to concrete surface area) for the das anodes considered in the model.

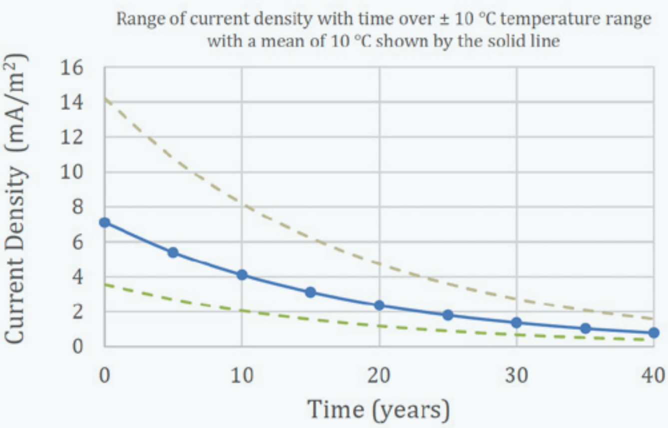


Figure 7: Current density vs time for the das anodes considered in the model.

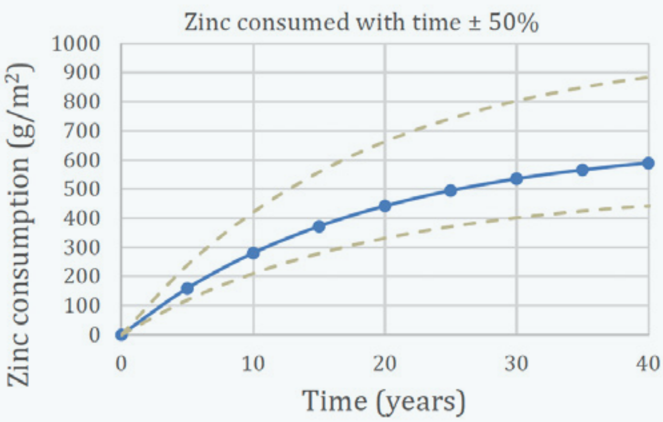


Figure 8: Zinc consumption vs time for the das anodes considered in the model.

Design of 2-Stage Cathodic Protection System

It has been shown that delivery of a high charge over a relatively short time in the order of a few months can arrest corrosion [8,9]. Once passivation of the steel is achieved, corrosion prevention current density is required to protect the steel reinforcement and this current must be maintained long-term to avoid reestablishment of corrosion.

The parameters that need to be controlled for such a system to be successful were determined by controlled lab experiments and field trials [1,2,8,10]. The primary parameter was shown to be the delivery of sufficient charge over a limited period applied at a high current density to establish a reservoir of alkalinity around the steel reinforcement by the cathodic reaction (eq. 2),

$$i_t = i_0 e^{-\lambda t} \qquad \text{Eq. (1)}$$

The negative charge also repels chlorides away from the steel surface [10], so the net effect is repassivation of the steel reinforcement. Laboratory experiments showed that repassivation of the steel depended on the level of chloride at the steel surface [8]. For example, at a constant current density of 50 mA/m^2, it required around 75 kC/m^2 of charge to repassivate the steel when the chloride level surrounding it was of the order of 2% by weight of cement but a much higher 110 kC/m^2 was necessary when the chloride level was 4%. At a lower current density of 30 mA/m^2 it required more charge, around 120 kC/m^2, to repassivate the steel if the chloride level was 2%. This information and data collected from field trials established a methodology for designing a 2-stage galvanic cathodic protection system [9].

Each anode is capable of delivering approximately 50kC of charge and spacing of individual anodes is determined such that the total charge delivered per m^2 of steel surface area exceeds the threshold level for a particular level of chloride. Based on the information mentioned above from laboratory experiments and field trials and an added safety factor of two, the charge delivery during Stage- 1 needs to be of the order of 100 kC/m^2 for every 1% of chloride. As an example, for a chloride content of up to 2%, the total system should be designed to deliver at least 200 kC/m^2 of steel. For a steel density of 1 m^2 steel /m^2 of concrete and knowing that a minimum of 50 kC of charge is delivered by a single anode, the requirement is to install 4 anodes in each 1 m^2 of concrete surface area.

There is an additional requirement that the subsequent current density delivered by the galvanic element of the anode unit should be sufficient to provide corrosion prevention for the design life of the system, e.g. a current density of 0.4 mA/m^2 at Year-30. The additional period of protection compared to the earlier example in concrete repairs is possible because of the guaranteed arrest of corrosion during Stage-1. The procedure then becomes the same as for the anodes used for concrete repairs where the Aging Factor of the anode is taken into consideration and the spacing of anodes is calculated to achieve the required current density at the end of the design life. It is essential that the calculated spacing achieves both the charge delivery requirement of Stage-1 and the long-term current density required during Stage-2. An example of a design for a bridge in Wales, UK [9] is detailed below.

To design the Two-Stage CP system for the case study included in this study, a survey, which included potential mapping, chloride analysis, steel cover depth and a visual survey was completed. The surface area of steel per m^2 of concrete surface requiring protection was calculated. The charge delivery requirement during Stage-1 was calculated based on a mean chloride concentration at the depth of the reinforcement plus one standard deviation. This level of chloride content (mean + 1 standard deviation) was approximately ~2.4% by weight of cement. The charge requirement for Stage-1 was therefore 240 kC/m^2. The steel density varied between 0.6-0.7. the minimum charge required for 1 m^2 of concrete, i.e. 0.7 multiplied by 240 kC/m^2, was 168 kC/m^2 of concrete surface, require the use of 3.4 anodes per square meter of concrete each delivering a minimum of 50 kC of charge. A spacing of 500 mm on center was chosen in this case which translates to 4 anodes per m^2 of concrete. This exceeded the minimum charge requirement of 240 kC/m^2 for Stage 1 and, more importantly, it ensured sufficient current for Stage- 2. Continual monitoring revealed that the current density was of the order of 20-80 mA/m^2 and the total charge, delivered in a period of about 100 days was at least 300 kC/m^2. The subsequent current density, once Stage-1 was completed, stabilized at about 1 to 2 mA/m^2. Confirmation that the treatment was successful was performed by measuring depolarized potentials 24 hours after disconnection of the anodes at different stages of the process. The depolarized potential became more noble during Stage-1 and 8 stabilized at a passive potential more positive than -150 mV vs a standard silver/silver chloride, 0.5 M KCl electrode (Fig. 6).

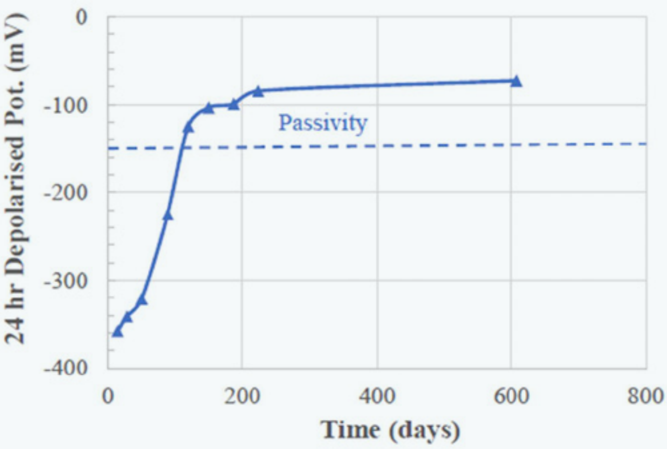


Figure 6: Example of the change in 24 hour depolarized potential in a zone where 2-stage anodes were installed in a bridge in wales, uk.

Steel depolarization over 24 hours was frequently performed. Depolarization values throughout Stage-1 exceeded 150 mV and for a period approached 250 mV. As the current density dropped during Stage-2, depolarization fell below 100 mV with a mean of around 80 mV.

CONCLUSIONS

Understanding the long-term performance of galvanic anodes over time in terms of aging and the effect of temperature has enabled a design procedure to be developed which ensures that a minimum mean current density is delivered throughout the entire design service life. The minimum mean current density should be adjusted as appropriate based the corrosion risk level. This design approach is consistent with the design approach outlined in "NACE SP0216-2023, Galvanic Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures".

For corrosion prevention applications, such as the use of galvanic anodes in concrete repairs, a table of risk in relation to level of chloride contamination at the depth of the steel reinforcement was established based on literature, laboratory experiments and field trials. The current density required at the end of service life was thus determined to be between 0.4 and 1.6 mA/m^2 depending on the level of chloride.

A proposed design procedure was established for the use with galvanic anodes in concrete repairs as described in the paper, and a graph illustrating the relationship between anode spacing, steel density and corrosion risk was calculated and presented.

For corrosion control applications, such as the use of galvanic anodes in concrete overlays and jacketing of corroding reinforced concrete elements, a table of risk in relation to level of chloride contamination at the depth of the steel reinforcement was established based on literature and field trials. The current density required at the end of service life was thus determined to be between 0.6 and 2.4 mA/m^2 depending on the level of chloride.

An example illustrating the design of a 2-stage cathodic protection system which comprises initial impressed current to passivate corrosion of the reinforcing steel, followed by galvanic cathodic prevention to maintain passivity was described. The design example illustrated how the total charge applied during the impressed current stage should be determined and how it should be adjusted based on the corrosivity (chloride content) of the concrete. Field performance results confirm the effectiveness of the self-powered impressed current passivation stage and the early galvanic performance achieved using this design approach. To assure long-term performance of the installed system, it is important to consider how galvanic anodes behave over time and to design the galvanic portion of the installation to ensure the design minimum current density to the steel is met or exceeded over the entire design / service life and is not just provided temporarily at the beginning of the galvanic stage.

Since field performance data was used to develop the proposed design approach, users should have confidence in the performance of installed systems which are designed using this methodology.

REFERENCES

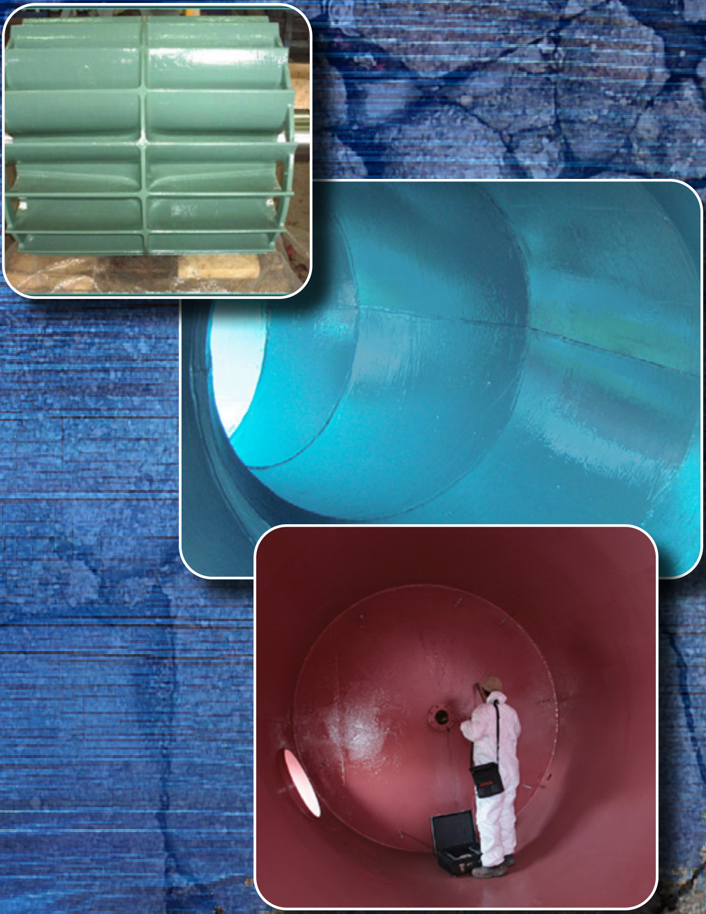
1. Sergi, G., Seneviratne, G., & Simpson, D. "Monitoring results of galvanic anodes in steel reinforced concrete over 20 years", Construction and Building Materials, Vol 269, 121309, Elsevier, Feb 1 2021.
2. Whitmore, D., & Sergi, G. "Long-term Monitoring of Galvanic Anodes Provides Data to Predict Performance and Perform Intelligent Design of Galvanic Corrosion Control Systems for Reinforced Concrete Structures" Corrosion 2021, AMPP, Salt Lake City, (2021) Paper No. 16712
3. Sergi, G. & Seneviratne, G. "Improved design considerations for steel reinforcement corrosion control with galvanic anodes following performance evaluation from analysis of site data" Structural Faults and Repair, Edinburgh, UK, 2022
4. Cathodic protection of steel in concrete, Concrete Society TR 73, 2011
5. Corrosion of Steel in Concrete – Investigation and assessment, BRE Digest 444 Part-2, 2000
6. Bertolini L, Bolzoni F, Gastaldi M, Pastore T, Pedeferri P, Redaelli E. Effects of cathodic prevention on the chloride threshold for steel corrosion in concrete. Electrochim Acta. 54 (2009) 1452–63.
7. Sergi G. Ten-year results of galvanic sacrificial anodes in steel reinforced concrete. Mater Corros. 62 (2011) 98–104
8. Rathod, N., Slater, P.R., Sergi, G. and Seneviratne, G. 'A Suggestion for a Two-Stage Corrosion Mitigation System for Steel Reinforced Concrete Structures' Proc. EUROCORR 2018, 102036, Kraków, Poland, (9 September 2018) 9. Sergi, G., Seneviratne, G. and Simpson, D. "Long term control of corrosion of steel reinforcement by a two-stage cathodic protection method" Concrete Solutions, MATEC Web of Conferences 361, 0 (2022) https://doi.org/10.1051/matecconf/202236102004
9. Sergi G, Seneviratne AM. Extending the service life by electrochemical treatment of steel reinforcement. In:
10. Proceeding of the RILEM International workshop on performance-based specification and control of concrete durability. (2014). p. 385–92.

AUTHOR DETAILS

Whitmore, David is the corresponding author of this paper. He is President and Chief Innovation Officer at Vector Corrosion Technologies, a position he has held since 2009. He is responsible for overall management and development for the company.

Sergi, George is Technical Director at Vector Corrosion Technologies, a position he has held since 2009. He is responsible for the fundamental research and development activities of the company and oversees a small team of researchers.

Simpson, David is Operations Director at Vector Corrosion Technologies. David is currently responsible for Research & Development for the group, International Manufacturing and Sales & Marketing within the European territories. He has been with the Vector family since 2010.



Extending the Service Design Life of Sewage Assets using Hybrid PU Linings In Central Queensland

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

Keywords: Waterproofing, Hydrogen Sulfide (H_2S) Gas, Long Term Durability, Anticipated Service Design Life, Concrete Durability, Low Cover.

This case study provides an overview regarding application of Hybrid Polyurea/Polyurethane lining on four, steel reinforced concrete, sewage treatment plants in North Queensland to protect the assets from aggressive Hydrogen Sulphide (H_2S) environments where the existing Pure Polyurea elastomer lining failed after six years' service, being in installed in 2012.

This paper describes the expectations of the consultant (Jacobs Engineering), aligned with expectations of the asset owners regarding extending the anticipated service design life of the asset by an additional 25 years and a 10 year product performance warranty, project time frames, the waterproof lining system that was selected for use, why this technology was nominated and approved for use by the consultant, and the site challenges encountered during application caused by SSD (saturated surface dry) concrete and extensive sectional loss of the concrete.

INTRODUCTION

In 2018, Jacobs Engineering Consultants in Brisbane approached the supplier to provide a protective lining and concrete repair proposal to remediate, protect and extend the service life of four steel reinforced, concrete sewage treatment plants from aggressive Hydrogen Sulphide (H_2S) environments where the existing Pure Polyurea elastomer lining failed after six years' service, after being installed in 2012. The four sites were located at.

- Mackay North Water Recycling Facility (MNWRF) for Mackay Regional Council.
- Mackay South Water Recycling Facility (MSWRF) for Mackay Regional Council.
- Cannonvale STP (CSTP) for Whitsundays Regional Council.
- Proserpine STP (PSTP) for Whitsundays Regional Council.

Failed Pure Polyurea linings at Mackay North Water Recycling Facility.

DISCUSSION

A condition assessment report identified the concrete had up to 20mm sectional loss (nominal) which required reinstatement so minimal cover over the steel reinforcement was maintained. Concern was the amount of section loss of concrete measured after the assets had only been in service for six years.

Upon review of each asset, the Hydrogen Sulphide (H_2S) levels at these four sites was measured at an average of 250ppm, with peak levels as high as 600ppm.

Various protective coating systems were considered, including high build epoxy, welded HDPE liner and elastomeric Polyurea/Polyurethane lining, ultimately the latter was selected due it's long-term performance in sewage environments.

As per typical for concrete assets showing deterioration from Hydrogen Sulphide (H_2S), the corrosion was isolated to above the water line (gas zone), with all submerged concrete remaining in good condition.

Vertical concrete wall showing extent of concrete loss, exposing steel reinforcement.

PROJECT SCOPE

- Remove the existing failed Pure Polyurea lining.
- Undertake condition assessment and identify extent of concrete requiring remediation.
- Dry abrasive blast defective concrete to remove all low strength material, back to sound substrate. In some cases, this involved complete removal of concrete from entire walls back behind the steel reinforcement.
- Testing was undertaken by 3rd party to measure concrete hardness, chlorides levels and carbonation levels.
- Clean steel reinforcement back to bright steel and apply anti-passivating primer, apply concrete bonding agent to prepared concrete and reinstate sectional loss using a high strength, polymer modified structural repair mortar.
- Once the repair mortar was fully cured, apply two-component, solvent free, elastomer hybrid Polyurea/Polyurethane lining embedded in non-woven, 100% polypropylene geotextile fabric, "heat-set" on one side, weighing 250 to 313 g/m².

Complete walls requiring concrete reinstatement.

The Lining Technology – Hybrid Lining...The Best of Both Worlds

Urea Portion of the chemistry is based on Aromatic Amine, not an Aliphatic Amine which provides;

- Extremely low moisture vapor transmission rate
    - ✓ Can be used as a moisture barrier with geotextile fabric layer
    - ✓ Resists cold-wall effects better than elastomeric Polyurea and Polyurethane
    - ✓ Suitable for long term service in immersion (Long track record)
- High strength and excellent abrasion resistance of Polyurea
- Good elongation and flexibility of Polyurethane
- Slower set than elastomeric Polyurea allows time to wet the substrate and achieve better adhesion.
- Slower set than elastomeric Polyurea allows the material to flow in and fill voids under coating (minimizing voids, helps eliminate potential sites for blistering to start). Able to fill bug holes.
- Allows use of whip-hose to spray gun.
- Only one hose to the gun, vs. two or three for conventional Polyurea's (Manipulating one hose doesn't fatigue the applicator as much, therefore yielding better applications, especially on walls and ceilings).
- Less complicated spray gun.
    - ✓ Uses plural pump and conventional airless spray gun which is easier to maintain.
- Allows use of geotextile membrane – there is enough 'open' time to embed the fabric (Conventional Polyurea sets up too fast to use embedded membranes)
    - ✓ Geotextile application allows bridging over irregularities, cracks, joints, etc.
    - ✓ Eliminates the need to resurface some deteriorated surfaces.
- Allows for embedding aggregate for non-skid applications.

Basic Chemical Reactions:
1. Urea = reaction between Isocyanate and Amine.
$RNCO + R^1NH_2 \Rightarrow RNHCOR^1$ Urea
2. Urethane = reaction between Isocyanate and Alcohol.
$RNCO + R^1OH \Rightarrow RNHCOOR^1$ Urethane

Chemical Composition vs Technology Type			
Part A		Part B	
Resin Component	Chain Extender	Curing Agent	Technology Type
Polyether Amine	Amine terminated	Isocyanate	Pure - Polyurea
Polyether Polyol	Amine terminated	Isocyanate	Polyurea/Polyurethane - Hybrid
Polyether Amine	Polyol terminated	Isocyanate	Polyurethane/Polyurea - Hybrid
Polyether Polyol	Polyol terminated	Isocyanate	Pure - Polyurethane

The Lining Technology – Product Description

The Elastomeric Hybrid Polyurea/Polyurethane is a solvent free, flexible, thermosetting elastomer lining, which eliminates creation of pinholes due to solvent evaporation, producing a dense monolithic membrane, with high resistance to abrasion and chemicals.

The lining is highly impermeable and can be placed in service within moments after application on concrete and steel substrates and fully immersed in water after one hour cure.

The product is sufficiently elastomeric to withstand normal shrinkage cracks in concrete without breaking and is an ideal immersion lining.

Asset Owners & Specifiers	
Feature	Benefit
Greater than 35 years track record	Predictable long-term performance
Excellent chemical and abrasion resistance	Long term asset protection
Elastomeric with 43% elongation to break	Excellent for concrete surfaces, can accommodate movement in the concrete surfaces including cracks
Extremely low water permeability	Excellent long term performance
Solvent free	Reduced solvent emissions Increased production efficiency

Applicators	
Feature	Benefit
Solvent free	Less paint consumption, Less application time Less waste, Less use of cleaners
Excellent application properties through plural airless spray equipment	Increased production rates, ability to coat and encapsulate difficult shapes and surfaces including bolts and rivets
Crack bridging system	Reduces concrete surface pre-preparation before coating to increase productivity
Fast curing	Rapid return to service and improved productivity and contract scheduling
Supplied as large kit sizes	Less down time and wastage, improved productivity
High film builds in a single coat	Improved productivity, encapsulates nuts and bolts

Why Was This System Chosen

Important to Jacobs Engineering was that the structural repair mortar and lining materials needed to compatible and from a single source supplier since a product performance warranty was an expectation.

The lining needed to be resistant to levels of Hydrogen Sulfide (H_2S) up to 600ppm.

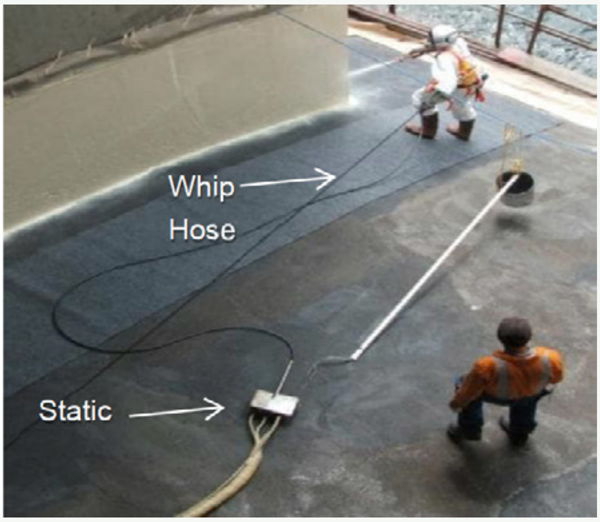
The lining needed to show successful track records of service in similar exposure environments and provide a ten year product warranty with an anticipated 25 year service design life.

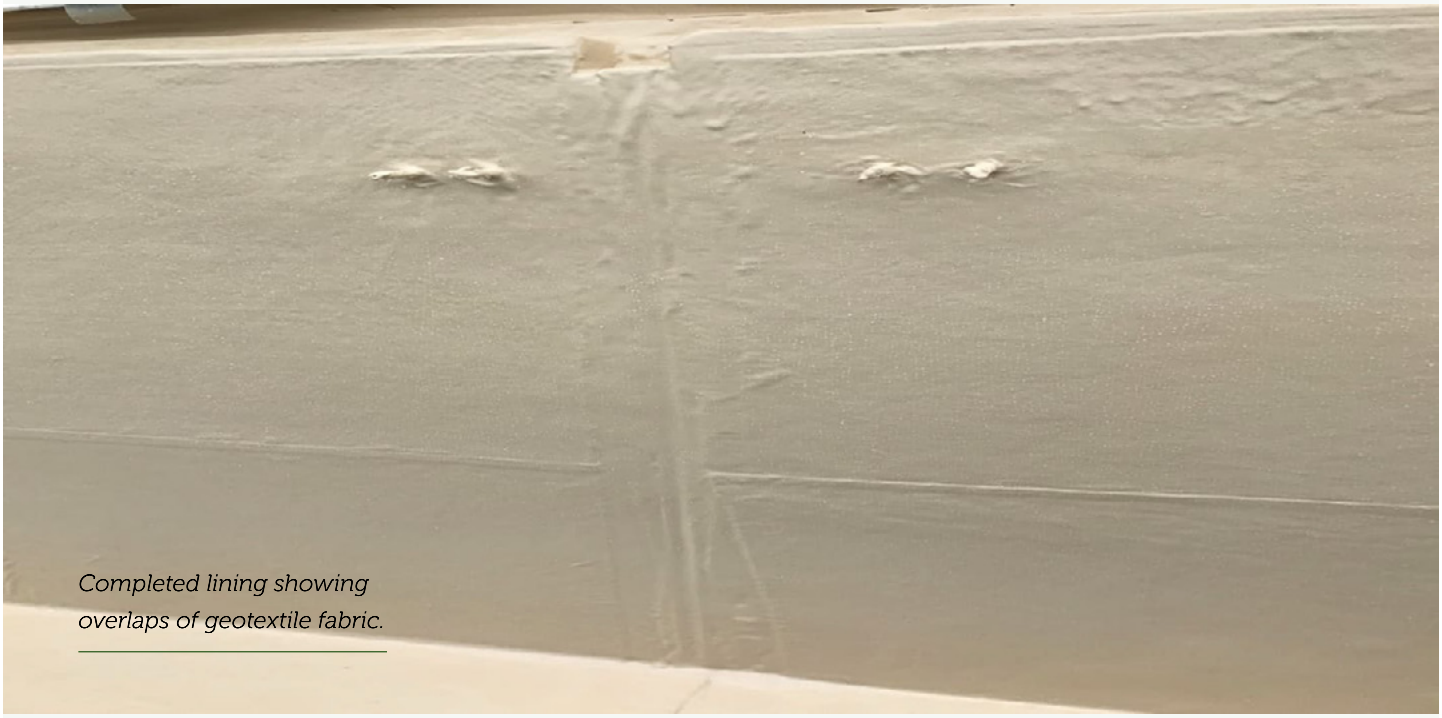
The lining needed to be suitable for application of SSD (saturated surface dry concrete), with FRTS capabilities.

Method of Application

The single component, polymer modified structural repair mortar was wet sprayed onto the substrate using a small aggregate mortar pump.

The Elastomeric Hybrid PU lining was spray applied using a twin-feed plural pump, consisting of twin pots for Part A & Part B, heated feed lines, connecting to the manifold and static mixer block where the two components are mixed. The mixed material is then fed through the single line whip end hose which is connected to the spray gun.





Completed lining showing overlaps of geotextile fabric.

CONCLUSIONS

Since application in 2018, the four assets have periodically been taken off-line to conduct visual inspections of the linings, which are all performing as per customer expectations by protecting the assets from abrasion and Hydrogen Sulphide (H_2S) attack.

Elastomeric Hybrid Polyurea/Polyurethane linings have more than 35 years of successful track records in the water industry, offering outstanding chemical and and abrasion resistance as well as significant application advantages including:

- Application to concrete and steel substrates.
- Fast Return to Service (FRTS) ensuring assets can be returned the same day.
- Can be fully emersed in water after one hour cure.
- Outstanding corrosion protection and extended service design life (up to 30 years) on concrete and steel assets in sewage environments.
- Embedded geotextile system allows the lining to be applied to SSD (saturated surface dry concrete)
- Application up to 5mm thick in a single coat

ACKNOWLEDGEMENTS

Satintouch
64 Mica Street, Carole Park, QLD, 4300

Jacobs Engineering
Levels 5-7, 32 Cordelia Street, Brisbane, QLD 4101

Completed Hybrid PU lining installed in inlet channel at Mackay South Water Recycling Facility.

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.

Enhancing High-Rise Longevity: The Power of Cathodic Protection

By Samir Cheytani

High-rise buildings located in coastal areas can face significant challenges from corrosion, especially in vulnerable concrete elements such as cantilevered balconies and columns. The prevalent cause of damage is typically chloride-induced corrosion, where chlorides from the sea penetrate the concrete elements over time, leading to corrosion of the steel reinforcement. During the life of a building, this deterioration can cause delamination and spalling in concrete elements and can lead to potential safety hazards and expensive repairs. To address the issue, electrochemical protection systems such as Impressed Current Cathodic Protection (ICCP) and Galvanic Protection Systems have proven to be highly effective in preventing further corrosion.

A recent example of this approach is a seven-storey residential building in Freshwater, Sydney, constructed in the mid-1970s. At the time of cathodic protection installation, the building was 45 years old and showed significant signs of corrosion in balconies and columns. A combined system was installed: ribbon anodes were embedded in the balcony slabs, and discrete anodes were drilled into the building's columns. ICCP was applied in severely affected areas, while Galvanic Protection was used in lower-risk zones.

The total cost of the CP system installation was approximately $1.5 million. This strategic combination not only addressed the varying levels of corrosion but also offered a cost-effective, long-term solution for the asset's durability.

Following the installation, a contract was established for the monitoring of the corrosion protection systems, conducted according to Australian Standard AS 2832.5 for steel in concrete. The combination of ICCP and Galvanic Protection not only halted further corrosion but also extended the life of the building, resulting in substantial long-term savings on maintenance.

In conclusion, ICCP and Galvanic Protection technology can offer a proven and cost-effective solution for corrosion prevention in concrete structures. By customising the application of these systems based on corrosion severity and environmental conditions, body corporates can ensure that high-rise buildings remain durable and structurally sound for years to come. The building inspection and corrosion protection system design was completed by Remedial Technology Pty Ltd, with the repair and CP installation carried out by Marine and Civil Maintenance Pty Ltd.

About the Author

Samir is the Operations Manager at Remedial Technology Pty Ltd. He specialises in assessing concrete structures affected by steel reinforcement corrosion. His expertise spans site investigations, electrochemical testing, data analysis, and rehabilitation design. Samir holds a Bachelor of Property Economics from UTS (2005) and a Master of Philosophy in Material Science and Engineering from UNSW (2020).

Deep Well ICCP for Steel Piles of a New Bridge Over a River

S. Ali, F. Papworth

Building and Construction Research and Consulting (BCRC)

The construction of the New Dubbo Bridge, spanning 662.59 meters across the Macquarie River in New South Wales, presents significant challenges related to steel corrosion. The bridge's 89 tubular steel piles, embedded up to 60 meters underground, are exposed to severe soil conditions characterized by low resistivity and high moisture content, increasing the risk of premature corrosion. Without proper protection, these piles could suffer from corrosion-related deterioration, leading to increased maintenance costs and a reduced service life. To mitigate these risks and extend the bridge's 100-year design life, a Deep Well Impressed Current Cathodic Protection (ICCP) system was designed and implemented.

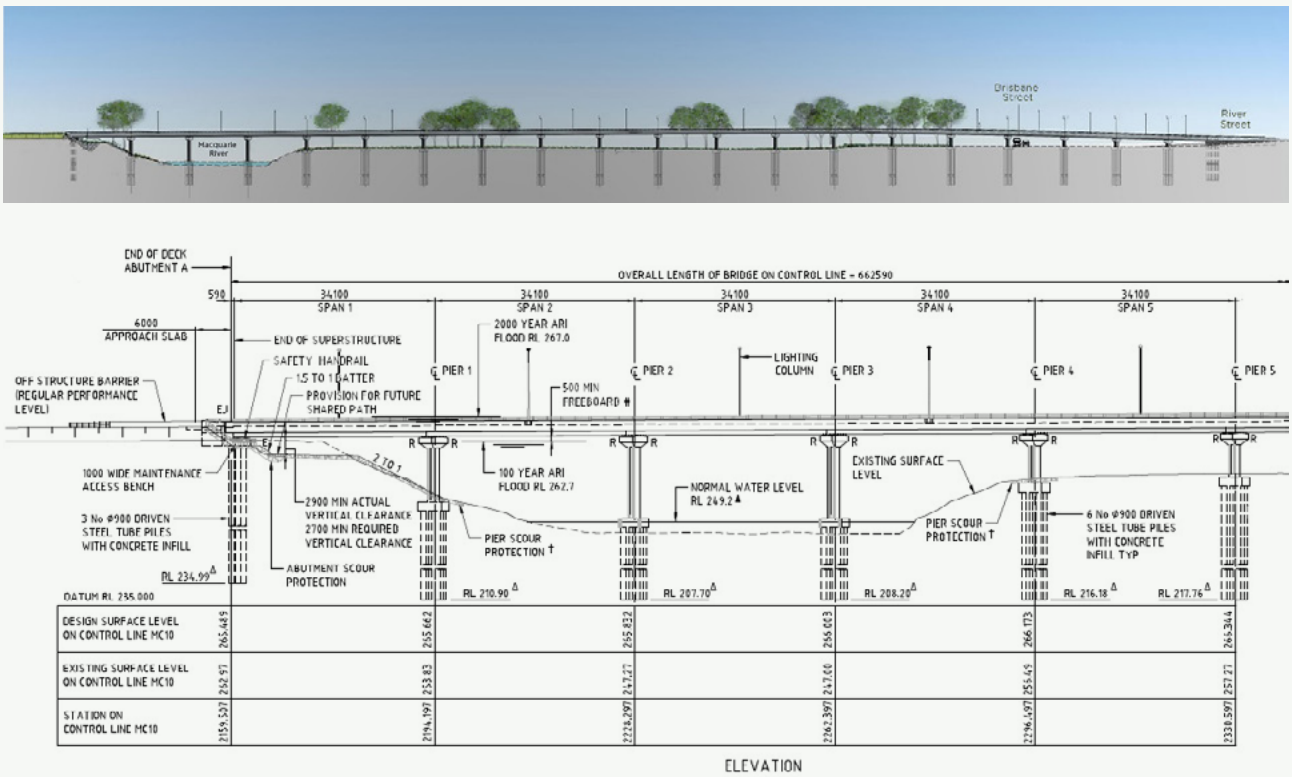


Figure 1: Shows a schematic and a section of drawing indicating the locations of steel piles in the bridge.

Methodology for Detailed Design

The ICCP system was developed following AS 2832.1 standards, incorporating detailed geotechnical data and corrosion risk assessments. Key components of the ICCP system included:

- **Deep Well Anode Groundbeds:** Installed to optimize current distribution while reducing land use requirements.
- **Transformer-Rectifier Units (TRUs):** To control current supply for each protection zone.
- **Zoning Approach:** The bridge was divided into seven cathodic protection zones, ensuring precise current delivery based on soil resistivity and pile surface area calculations.

Soil resistivity testing, using the Wenner four-pin method, was conducted to assess the variation in corrosivity across different depths. The findings demonstrated multi-layered soil conditions, where upper layers were more corrosive than deeper strata. This highlighted the need for deep well anodes to bypass high-resistivity zones and effectively distribute protective current to all piles.

The system was optimized using SES CDEGS software, which simulated:

- Current attenuation along pile depth
- Ground potential rise (GPR) calculations
- Impact of soil layering on resistance values

Each deep well groundbed consisted of MMO anodes arranged in series, ensuring efficient current dispersion across all pile surfaces.

Results – Design Data

Calculations were completed to determine the details of the deep well anode groundbed. The design of the cathodic protection system for this bridge involved segmenting the bridge into seven cathodic protection zones, each covering three spans. These zones were defined based on the surface area ratio of the piles within each zone relative to the total surface area of all piles. Soil resistivity was measured for each zone, and the average resistivity was assigned to guide the CP system design for the respective zones. Total CP current required was calculated to be 214.8A to achieve compliant CP on the piles, i.e. 89 piles with diameters varying from 900mm to 1200mm and buried depths between 25m to 42m. This current is based on the current density of 20 mA/m^2 for bare steel in the soil as per AS2832.1.

Deploying deep well anodes strategically under the bridge, midway between the piers, allowed for efficient use of the existing right-of-way, thereby reducing costs associated with securing additional space for installation. A schematic showing an example of the groundbed location is presented in Figure 2.

Environmental considerations were taken into account in the design of the anode well. Three possible environmental risks with well drilling are surface water runoff, interchange between aquifers, and contamination by groundbed materials. To prevent the possibility of pollution by surface water runoff, the closed-hole system was deployed by considering the anode hole to be cased and sealed. A concrete slab (1500 mm x 1500 mm x 100 mm) and a covered pit were considered in the detailed design report for the installation of the holes to prevent pollutants from running off into the hole. To ensure the safety of the personnel and public, the ground potential riser surrounding anode wells was evaluated. Step and touch voltage calculations were performed for all anode wells and it was ensured

Parameter	Value
Anode Type	Mixed Metal Oxide Tubular Ti - ASTM B265 Grade 1 or 2 and certificated as per NACE TM0108-2012
Anode Dimensions	1000 mm x 25.4 mm
Backfill	SC-3 Loresco Carbon Backfill
Cable Tail	PVDF/HMWPE single core multi-stranded
Vented	Yes
Rated Output	5 A for 20 Yrs; 4 A for 25 years
Number of Anodes in well	10
Groundbed Depth	30 m
Groundbed Diameter	0.168 m
Anode Spacing	1.5 m

Table 1 – Anode Groundbed Details

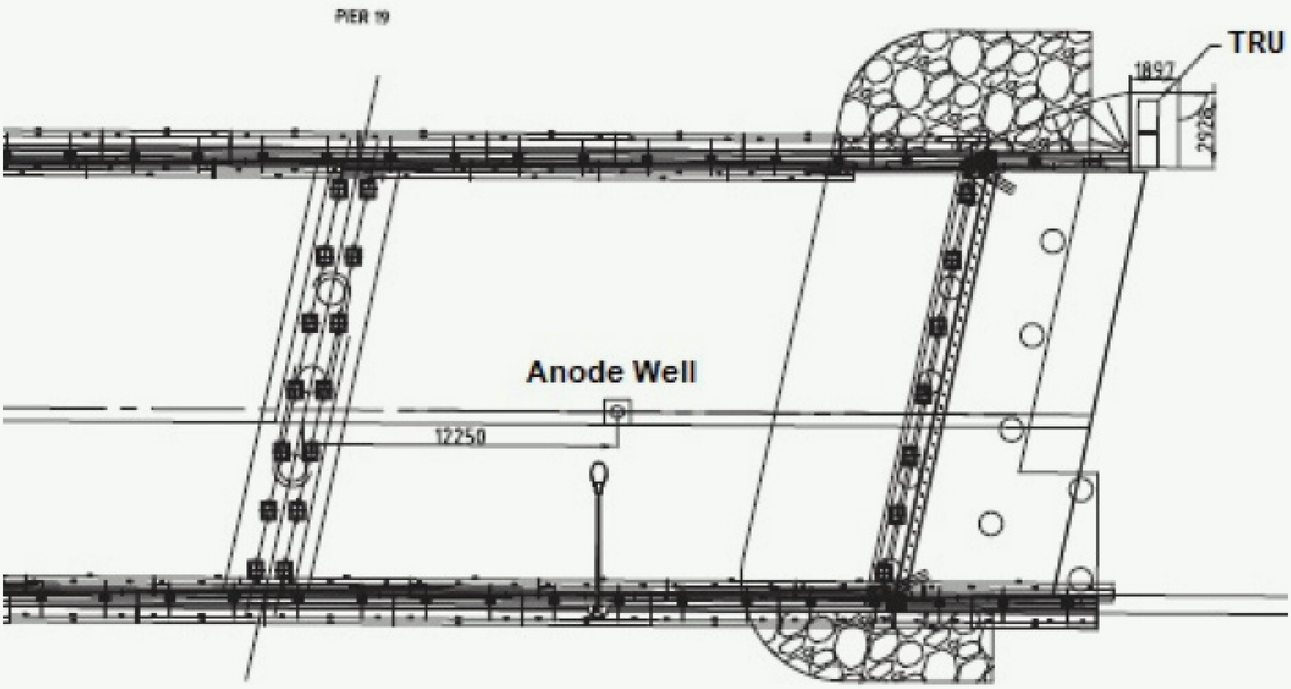
that ground potential rise and the resulting step and touch potentials around the anode wells are within the safe limits for the personnel and public. Note the ICCP system is remotely monitored via GPS interrupter with Cellular remote monitoring module.

Table 1 shows the groundbed details considering the resistivity measured for each zone in Table 2. A summary of the design details are in Table 3.

One	Structure	Number of Piles	Current Req. (A)	Zone Resistivity (ohm.cm)
TRU-1	Abut. A	3	32.74	6891
	Pier 1	6		
	Pier 2	6		
TRU-2	Pier 3	6	40.25	6891
	Pier 4	6		
	Pier 5	6		
TRU-3	Pier 6	6	28.20	7948
	Pier 7	3		
	Pier 8	3		
TRU-4	Pier 9	3	23.58	7948
	Pier 10	3		
	Pier 11	3		
TRU-5	Pier 12	3	26.01	3330
	Pier 13	3		
	Pier 14	3		
TRU-6	Pier 15	3	28.52	3524
	Pier 16	3		
	Pier 17	3		
TRU-7	Pier 18	3	35.55	3821
	Pier 19	3		
	Abut. B	11		

Table 2 – CP Zoning

Figure 2: Example of drawing showing the location of groundbed (anode well) to piles.



1. The number of anodes (A_N) required to provide protection over the design life is calculated based on the average protective current.

   $A_N = I_t/I_s = 7$ No.
   Where:
   I_m= 5 amps (Manufacturer's rated output)
   T_m= 20 yrs (Manufacturer's design life)
   I_t= 32.7 amps (Total system protective current)
   t_d = 20 yrs (Design Life, DL)
   I_d= 5 amps (Max. individual anode current for DL)
2. The minimum backfill mass (BM_{min})required to achieve the design life and protective current.

   $BM_{min} = C_m \times I_t \times t_d = 654$ kg
   Where:
   C_m= 1 kg/A yr (Backfill consumption rate)
3. The actual backfill mass (BF_A)to meet design life and protective current requirements.

   $BF_A = BF_d \times (GB_v - (N \times A_v))$=1523 kg
   Where
   A_v= 0.001 m³ (Individual anode volume)
   GB_v= 1.287 m³ (Individual active column volume)
   N= 10 (Design number of anodes)
   BF_d= 1188 Kg/m³ (Backfill density)
5. The total resistance of the groundbed (GB_t) including the header cable and parallel anode configuration.

   GB_t= $1/(1/R_{h1}+1/R_{h2}+\ldots 1/R_{hn})+R$ = 1.293 ohms
6. The total positive circuit resistance (R_{pos}) including the main positive cable and anode groundbeds.

   $R_{pos}=R_m + GB_t$ = 1.298 ohms
   Where:
   R_m= 0.052 ohms (Main positive cable resistance)
7. The total negative circuit resistance (R_{neg})

   R_{neg}= Main Negative Cable Res. = 0.010 ohms
8. The total circuit resistance is (R_{total})

   $R_{total}= R_s+R_{pos}+R_{neg}$ = 1.758 ohms
   Where:
   R_S= Structure: electrolyte resistance = 0.45 ohms
9. The CPU Rating (V_{min}) is then assessed.

   $V_{min}= I_t \times R_{total} + V_{EMF}$ = 59.5 Volts
   Where:
   V_{EMF}= 2 Volts (Back EMF)

Table 3 – example of measurements and calculations for cpu rating

Conclusion

The ICCP system designed for the New Dubbo Bridge demonstrates a robust and scalable approach to protecting steel piles in corrosive environments. By leveraging deep well anode technology, optimized zoning, and advanced simulations, the system ensures long-term durability while meeting regulatory standards. This project highlights the importance of early corrosion assessment, precision engineering, and proactive maintenance in ensuring the resilience of critical infrastructure.

Future developments in ICCP technology, including the use of AI-driven predictive maintenance and advanced real-time monitoring, will further enhance the sustainability and cost-effectiveness of cathodic protection systems. As infrastructure ages, the adoption of cutting-edge corrosion control measures will be essential to maintaining safety, functionality, and longevity in major construction projects.

Visit the website to view/download the full paper.

Queensland Branch AGM & Social Event Recap

Despite the weather attempting to dampen our spirits once again—after already forcing a postponement due to Cyclone Alfie—our Queensland BGM and Social Event went ahead with great success! The majority of the 25+ registered committee members, partners, and guests made it to BrewDog microbrewery, where an evening of networking and camaraderie unfolded.

Although the rain led to some venue capacity challenges, it was fantastic to see a diverse, cross-generational turnout. From the Rusty Nuts to the Young Corrosion Professionals (YCP), partners, and some fresh faces, everyone actively engaged in conversations and made meaningful connections throughout the night.

A highlight of the event was welcoming Isaac Isakovich back to the branch committee following his tenure in the National Office. His vast experience in association governance will undoubtedly serve our branch and members well in his new role as a Council Branch representative.

Special Thanks to Our 2025 Branch Partners

A heartfelt thank you to our 2025 Branch Partners—Scape, Denso, and International Paints—for their ongoing support. Their contributions are invaluable in helping us deliver quality events and industry engagements throughout the year.

Looking Ahead:

Upcoming Events & Industry Engagements

We're excited for a dynamic year ahead, with several key events on the horizon:

- **Joint Young Professional Lawn Bowls Event**
  May 2nd at BOO Bowls Club, Brisbane, proudly supported by Scape and Denso.
- **Cairns Technical Event**
  Planned for June/July, with thanks to Oscar from Remedy AP for his support.

Plans for the Second Half of 2025 Include:

- Technical events offering insights into asset owners' corrosion challenges
- Discussions on emerging technology innovations
- A potential site visit

We look forward to another fantastic year of learning, collaboration, and industry engagement. Thank you for your continued involvement and support of the Queensland Branch!

UQ Career Panel Update:

The UQ Environmental & Material Engineering Major Night gave us the opportunity to share our passion and experiences with aspiring professionals. Environmental factors are key considerations for people working in corrosion prevention, so it was a interesting discussion. It was encouraging to find a large number of women attending the event, showing a keen interest in materials engineering for a greener future.

The Q&A session began with each panellist introducing their company and role, highlighting their contributions to the field. The importance of materials engineering was emphasized, noting its critical role in developing sustainable and efficient technologies. Environmental engineers were discussed as key players in traditionally non-eco-friendly industries, driving initiatives to reduce environmental impact.

Panellists shared observations on the evolving responsibilities of environmental and materials engineers, anticipating increased focus on sustainability due to predicted environmental decline. Career highlights included breakthrough projects that significantly advanced environmental goals.

The benefits of timely maintenance for corrosion prevention were emphasized to the students, showcasing it as a key enabler for achieving both environmental and economic objectives.

Managing conflicts between environmental goals and project feasibility was addressed, with strategies like prioritizing long-term benefits and innovative solutions. It was also highlighted that in some cases, the most economic and durable solution to corrosion prevention is not always environmentally sound, and sensible compromises sometimes need to be made. The future of environmental engineering in civil engineering was discussed, with emerging technologies such as green infrastructure and smart materials being highlighted.

Common misconceptions about the field were debunked, emphasizing the diverse and impactful nature of environmental engineering work. Finally, the value of professional networking was underscored, with recommendations for key industry groups and events for students to engage with. Advice for students included seeking internships, networking, and staying informed about industry trends.

The South Australian Branch of the ACA held its Branch General Meeting on Friday 14th March 2025 at the Lord Melbourne Hotel. The attendees enjoyed collegial discussions, a few drinks and good food courtesy of the event sponsor Denso. We thank Denso and David Towns for their support of the SA branch.

BGM formalities included the election of Branch President Anthony Roccisano and Vice President Michael Carson and the appointment of two new committee members Yesh Sundarrajan and Kevin Shah. The SA branch would like to thank retiring committee members George Hobbs, Nick May and Daniel Fosdike for their dedication to the committee during their tenure. All other committee members have elected to remain on including branch Secretary Ramon Salazar Romero and Membership Officer Adam Levi. During the presidents report, members engaged in vigorous discussion and were united in their desire to improve the association and wanted to give back to the community.

Following the BGM attendees participated in the annual SA branch Quiz night with the team Trivia Newton John taking the win, congratulations to all! The event was well received and signals a great 2025 for the SA branch.

On a warm March evening in Port Melbourne, Victorian corrosionists gathered once again for the highly anticipated Young vs. Old(er) lawn bowls competition.

Hosted by the Victorian Branch of the Australasian Corrosion Association (ACA) in partnership with the Young Corrosion Group (YCG), the event was more than just a friendly match—it was a chance for industry peers, both seasoned professionals and rising talents, to connect over pizza, good company, and, of course, some serious competition.

Buoyed by memories of their 2024 victory (and perhaps a few extra slices of pizza), the "Old(er)" team took an early lead. However, as the evening wore on and the sun dipped below the horizon, the younger players mounted a fierce comeback. With scores neck and neck heading into the final round, it was anyone's game. But in the end, experience edged out enthusiasm, with the veterans clinching victory by a mere two points.

With friendly rivalry, great company, and a touch of competitive spirit, the night was a resounding success. We can't wait to see what 2026 brings—will the young guns stage their revenge, or will wisdom win out once again? Stay tuned!

The event incorporated a site visit to the Air New Zealand maintenance hangar. This started with a classroom presentation where two AirNZ experts explained their maintenance procedures/inspections - where for example, every screw in every wing has a unique number and a record of its condition. If any corrosion is identified, it is inspected and reported to the Aircraft manufacturer's engineers. They assess the reduction in strength and send back a repair procedure. The second half was a walk around the hangar, where various aircraft in various states of repair were viewed.

We even learnt about how spilt coffee can affect the seat mounts. The whole experience was very informative and AirNZ gave great explanations of the intricacies of their corrosion issues and coating procedures. The NZ Branch has good representation within the ACA management system, with Raed El Sarraf now President of the ACA Council and Trish Shaw on the ACA Board.

Inspiring the Next Generation: Guest Lecture at UTS Steel, Timber, and Design class on AS2312!

I'm delighted to share highlights from a recent guest lecture at UTS - University of Technology Sydney, organized by the Australasian Corrosion Association (ACA) NSW Branch. The lecture was presented by ACA NSW Branch President Adam Hockey and focused on AS2312.

A huge thank you to Dr. Bahar Mehdizadeh, Head of Research & Innovation at ACA NSW branch, for arranging this insightful session. Her efforts in fostering collaboration between industry and academia are truly commendable! The lecture was supported by UTS teaching staff Dr. Harry Far, Dr. Mina Mortazavi and Dr. Bahar Mehdizadeh.

Adam's presentation dove into AS2312: Guide to the Protection of Structural Steel Against Atmospheric Corrosion by the Use of Protective Coatings, an Australian Standard that provides specifications for paint coatings (Part 1) and hot-dip galvanizing (Part 2) to ensure steel structures remain durable in corrosive environments. This is critical, as corrosion costs Australia and New Zealand approximately AUD $100 billion annually (per ACA research), with best practices potentially saving 15-35% of these costs.

The session bridged industry expertise with academic learning, offering students and professionals valuable insights into sustainable design and corrosion management. It was a fantastic opportunity to inspire the next generation of engineers!

Take a look at a photo from the lecture!

The Western Australia Branch of the ACA is hosting its BGM in April, and we invite all members, their spouses or partners, and anyone interested in corrosion management to join us! This relaxed and informal gathering is a great opportunity to network, share ideas, and connect with fellow members and friends of the ACA. Whether you're a seasoned professional or new to the association, we'd love to see you there!

During the evening, we'll hold a brief Branch General Meeting (BGM) to discuss plans for 2025, elect committee members, and share how you can get more involved with the ACA.

We're particularly interested in hearing from members who are keen to:

- Join the committee
- Take an active role as Speakers, Organisers, or Sponsors for upcoming events.

Further details on the AGM will be updated soon. ***Stay tuned here.***

The Western Australia Branch is still looking for partners for 2025. If you're interested, please submit your interest here.

The Newcastle Branch held their Branch General Meeting (BGM) on Wednesday, March 26th, with both current and new members in attendance. A big thank you to the branch's president, Rhett Watters, for his outstanding contributions over the past two years, as well as to the entire 2024 committee for their efforts. Special recognition goes to Jim Hickey for his long-term commitment to both the branch and ACA nationally—we wish him all the best.

We are excited to welcome Andrew Dickinson as the new branch president. Having already been a part of the committee for some time, we look forward to his leadership and guidance for this year's committee.

The branch will be hosting a water-themed seminar in June—stay tuned for more details. Additionally, the Newcastle Branch is still looking for partners for 2025.

WANT TO KNOW MORE?
SUBMIT YOUR INTEREST HERE

Grant Chamberlain, President, NZ Branch

After 30+ years in the corrosion prevention industry, I have been involved in numerous and diverse range of petrochemical and other industrial projects. I have worn many hats: specifier, applicator, installer, inspector, and asset owner. I have prevented several potentially catastrophe failures by "hunting out" corrosion before asset failure occurred. I believe that being a coating inspector and a Cathodic Protection Technologist gives me a unique ability to provide my clients with a holistic approach to corrosion prevention.

Q1.
Where do you work? Describe your job.

I'm the owner of Cathodic Protection NZ Limited. My jobs ranged from sweeping the floor to designing CP systems.

Q2.
Can you share your journey into the corrosion industry? What motivated you to become involved?

I fell into the Corrosion Industry by chance. I was an explosives specialist for a Seismic Company when, in the 80s, the price of fuel dropped, and people stopped looking for it. I had to find another job. Ron Berry hired me as a QA inspector at TBS Coatings in New Plymouth. I then obtained my CBIP coatings inspector certificate, thanks to Willie Mandeno, Les Boulton and Kerry Dazell. I then worked as a third-party inspector for STOS on the Oaonui extension and the Maui B offshore installation. At the end of this contract, I moved to Auckland and became the coatings inspector at the Devonport Navy base. Working with Wayne Speer and Pat Conner. Eighteen months later, I moved back to New Plymouth, where I ran my own blasting and coatings business. Natural Gas Corporation ultimately became my major client, so Rene D'Ath hired me to work directly for them. At NGC, I developed and ran their coating maintenance program. The program covered Delivery Points and MLVs all over the North Island. While away at the sites, I would check the CP readings. As a coatings inspector, you get tired of telling painters, "You haven't painted under the pipes." Or "The thickness is only 320µm, and you are contracted to put on 400µm". CP involves a lot less interaction.

I then transitioned into full-time CP work and relocated to Auckland, where I was contracted to work on gas distribution piping. It was here that my CP troubleshooting knowledge expanded, as the distribution piping had every kind of fault imaginable that needed to be addressed.

I then moved to Christchurch and shortly after that bought CPNZ from Bob James' wife after he passed away.

Q3.
Who or what has influenced you most professionally?

Wayne Speer was my main influence. Wayne approaches CP in a very scientific manner. Wayne keeps all his results in dated notebooks, so if there is ever a query, he can refer back to his original field notes dating back to when he first began working with CP. Additionally, he set up his test gear to keep his hands free, which helped him achieve consistent results. Wayne also challenged other people's findings to ensure they had the evidence to back up their conclusions/recommendations.

Q4.
What has been the most challenging project you've worked on and why?

Sorting out the CP on the gas distribution system in Hamilton. This system had any fault imaginable.

Q5.
What do you see as the biggest challenges facing the corrosion industry today?

The quality of training provided by universities regarding corrosion prevention. On any large project, if something is going to go wrong, it will likely be with the coatings; however, young engineers often have little knowledge about coatings or CP.

Q6.

Have you noticed any emerging trends in corrosion that the industry should be aware of?

The use of consultants who lack experience and are overly conservative. I know of two CP systems that the consultant specified, an expensive ICCP system, and they are both running on one Magnesium anode with a resistor to choke back the current. With CP, you need to be doing it every day so that you are constantly learning and experiencing different situations.

Q7.

Where do you see the future of corrosion mitigation and management heading in the next decade?

Until universities begin producing engineers with knowledge about corrosion prevention and its importance, little will change. We might have AI writing fancy reports, but are they telling all the findings or just the good findings?

Q8.

What advice would you give to someone just starting their career in the corrosion industry?

Ask a lot of questions, and don't make presumptions.

Q9.

What has been your greatest professional achievement?

Keeping my boss/client out of jail. I like to think my job is to keep my boss or client out of jail by performing my activities in accordance with standards and clearly reporting my findings and making recommendations. This enables those above me to recognise the significance of the recommendations and provide the necessary funds to make improvements. So, if anything goes wrong, i.e. a corrosion-related gas leak, my boss/client can stand up in court and say that all practicable steps were taken to prevent this, and here is the evidence.

Q10.

How has being a member of the ACA benefited you professionally or personally?

Being able to meet other professionals in the corrosion prevention industry. Obtaining certification to prove my competence.

Troy Palmer

Troy Palmer is a Senior Technical Engineer with Marine & Civil Maintenance. He is a certified AMPP Coatings Inspector Level 2, AMPP Cathodic Protection Level 1 (Tester), and a member of Engineers Australia with over 9 years' experience in the infrastructure remediation industry. He has a wide variety of experience across concrete, steel, stone and timber structures, is an active member of the Australasian Corrosion Association (ACA) Concrete Structures & Buildings Technical Group, and in his current role helps lead a team of engineers specialising in asset management and durability.

Q1.
Can you briefly describe your background and how you came to specialise in corrosion?

In uni, I studied a multi-disciplinary branch called Integrated Engineering because I couldn't choose just one. I knew I would always have a broad engineering interest so it was more important to me to choose a career where I could indulge those interests, had opportunity to drive positive change, and where there would always be demand. The remedial industry ticked all the boxes and I like being on the fast-paced contracting side of the industry.

Q2.
Can you tell us about your current role?

I'm part of MCM's Engineering Services Team, which focuses on HSEQ improvements of MCM's contracting side and also some Early Contractor Involvement consulting, performing condition assessments, and inspection and testing. When I'm not performing inspections on site or writing reports, I'll be managing and auditing MCM's HSEQ systems or supporting our project operations.

Q3.
In your opinion, what makes corrosion a critical issue for Concrete and Structures specifically?

Creating steel and concrete infrastructure demands heaps of energy and resources and requires even more to maintain in those states. Corrosion is a natural equilibrium process and is inevitable, even with concrete structures which are often mistakenly assumed as permanent. With global material supply shortages, population and temperatures increasing to their projected peaks, and more annual emissions than ever recorded, reducing our demand for energy and resources is more important today than ever in history, and therefore so are efficient maintenance strategies.

Q4.
What are the most significant corrosion challenges facing your sector today?

Keeping up with corrosion has always been a challenge and I'm sure that will continue for some time. It's been about 50-60 years since durability was even considered with respect to reinforced concrete, and in that time there's been a massive infrastructure boom without having incorporated all the learnings from remediation. Heaps of structures built 50 years ago are now needing major repairs or refurbishment, so the challenge is to work with what we've got and resist the allure of starting again by demolishing and rebuilding. The most sustainable building is by far the one that already exists.

Q5.
Could you discuss any new technologies or materials that have emerged recently to combat corrosion in the Concrete & Structures area?

There have been so many improvements even just through my short career. One of the biggest game-changers in the last decade has been the introduction of remote monitoring equipment. Being able to tap into a control unit on the other side of the country cuts on-site time, avoids flights, etc. Protecting a structure is relatively straightforward, though knowing that it's protected takes specialised training and experience, so being able to record and interpret readings remotely makes specialised remediation strategies such as cathodic protection more accessible.

I've also had the pleasure working with MCM on their patented and innovative GreenTech Shield for Electrochemical Chloride Extraction (ECE) and Electrochemical Realkalisation (ER). A huge continuing investment is being made on this innovative system, reducing the energy and resource demand to maintain chloride-contaminated reinforced concrete.

Q6.
What are the key strategies for corrosion prevention and management that companies in the sector should implement?

I think the keys are to understand the root cause of defects and then target proactive maintenance with that in mind, rather than relying on one solution for various assets. If chlorides are the cause of corrosion defects, then take chloride concentration tests on a schedule. If it's carbonation, then a protective coating maintenance schedule is a top priority. It's too common that the cause (or even presence) of defects is unknown until the problem has gotten out of hand. Corrosion starts slowly and accelerates quickly, so act early where possible, and understand that 'pathology' of the structure.

Q7.
Where do you see the future of corrosion research and technology heading for Concrete & Structures sector you work in?

I've noticed that supplementary cementitious materials (SCM) like fly ash, slag cement, and silica fume have been in the limelight (pun intended) recently because they can replace Portland cement in concrete and offer reduced environmental impact, often improved durability, and potentially *lower costs. There's certainly more to explore on that side, however I think that's only part of the solution. Another part that interests me is a structured durability design process for reinforced concrete structures, for which some incredible Australians are paving the way forward. Under current Australian Standards, three different concrete structures which all meet the same criteria could result in three vastly different service life classes. The approach to designing a structure must change so that durability is at the forefront of design rather than a hindsight.*

Q8.

What advice would you give to asset owners of concrete structures to better address corrosion challenges?

I think that it's important to have a documented long-term asset management plan. It helps align interested parties, is a key to receiving funding, and improves productivity. The clients who have had a maintenance plan developed in coordination with asset owners and consulting engineers have been the most rewarding to work with due to the collaborative approach that comes from a shared goal.

A9.

Could you share a specific case where innovative corrosion management significantly improved operations, efficiency or safety?

We are nearing completion of a major remedial project at Queens Wharf in Lautoka, Fiji, for which MCM received the Excellence in Innovation Award at the 2024 Prime Minister's International Business Awards. A key innovation in this project was the application of GreenTech Shield, but our team also identified a significant cost-saving opportunity for the client: rather than installing new protective jackets to almost 250 steel piles, we upgraded and recommissioned the existing Impressed Current Cathodic Protection (ICCP) system. The CP system had been non-operational for at least five years prior to tender, however advancements in remote monitoring, Transformer Rectifier Units (TRU) - upgrading from a single-zone, oil-cooled manual system - along with the installation of additional reference electrodes for improved data collection, made refurbishment a practical and more effective solution. Additionally, we implemented a 10-year comprehensive maintenance and monitoring plan to ensure long-term performance and cost efficiency.

Q10.

How are data analytics and predictive maintenance being utilized to address corrosion-related issues in the industry?

I think it's helping transition maintenance to being proactive rather than reactive. This helps by detecting and addressing early stages of corrosion before it's taken hold, improving service lifetimes and structural and operational safety. For example, digital twins (AI-driven virtual replicas of structures) are allowing most of an assessment now able to be conducted from a desktop, which means more of a structure can be assessed in detail within a shorter period of time. That said, it's important to acknowledge that the data still needs to be collected in-situ, and you often can't completely replace someone being physically present. I think we're still in the early stages for some emerging technologies and by taking a look back my career only spanning less than a decade, I'm excited to see what will be possible in the next decade.

Nate Berends

Nate is a Senior Technical Engineer at Marine and Civil Maintenance, with a Bachelor of Civil Engineering and NACE CP2 certification. Since beginning his engineering career in 2016, he has developed experience in materials durability and corrosion mitigation, with a focus on electrochemical protection systems since 2023. As part of MCM's Engineering Services Team, Nate supports the delivery of technically complex remedial infrastructure projects and plays a key role in the company's research and development initiatives.

Q1:
What is your current ACA membership level?

I am a Corporate Platinum member's representative with the Australasian Corrosion Association (ACA), affiliated through the Young Corrosion Group (YCG).

Q2:
What is the Young Corrosion Group (YCG)?

The Young Corrosion Group (YCG) is a network within the ACA designed to connect and support young professionals and early-career individuals in the corrosion industry. It provides opportunities for members to collaborate, share knowledge, and develop both personally and professionally.

Q3:
Why are you a member of the YCG?

I joined the YCG because I enjoy connecting with others in the corrosion industry who work across a broad range of roles and disciplines. It's a fantastic way to build professional relationships, learn from peers, and stay updated on the latest techniques and developments. The group also offers opportunities to build new skills and take part in collaborative learning.

Q4:
What inspired you to pursue a career in Corrosion?

I was drawn to the corrosion industry because I enjoy working on the restoration and preservation of deteriorated structures—there's something really rewarding about extending the life of critical infrastructure. I'm particularly interested in the technical side of corrosion, especially electrochemical systems, and how we can use that knowledge to prevent further damage.

Q5:
What are some important corrosion-related issues facing your industry today?

One of the most pressing issues facing our industry is attracting and developing the next generation of corrosion engineers. As experienced professionals begin to retire, there's a real need to ensure that knowledge transfer and mentorship are taking place. At the same time, ageing infrastructure continues to be a significant challenge. Many assets are operating well beyond their original design life, so effective inspection, maintenance, and remediation strategies are more important than ever.

Q6:
How do you think the ACA and YCG support young people in the corrosion industry?

The ACA and YCG support young professionals by hosting social and networking events that foster community and connection. They also run technical events, that allow members to deepen their knowledge and stay engaged with the latest industry trends. These opportunities are invaluable for career development and staying informed.

Q7:
How can others interested in the YCG, join?

It's easy to get involved—just head to the ACA website and register your interest in joining the YCG. From there, the team will connect you with your branch president or YCG rep and provide details about upcoming events and how to get involved.

Paolo Alegro

We're delighted to begin our #densoawards series by featuring catchup interviews with the 2023 recipients of Denso's David Winn OBE Award!

Our first catchup interview (below) was with @ Paolo Alegro – a Materials Engineer at @Infracorr Consulting who received the Denso Training Scholarship.

Please join us in congratulating Paolo on his achievements and ongoing contributions to the corrosion prevention industry!

Q1.
Since our last update, what have been the key developments in your work with heritage structures?

One key area of development has been transitioning from the condition investigation phase to the remedial construction support phase for heritage structures. This shift involves responding to Requests for Information (RFIs) promptly and maintaining clear communication with clients and subcontractors to ensure the project runs smoothly.

Q2.
Can you discuss any new projects or specialisations you have explored within the corrosion prevention industry over the past year?

I've had the opportunity to engage in various cathodic protection (CP) projects, focusing on commissioning, monitoring, and design. Notably, I was involved in a CP commissioning project for a river bridge near Gladstone, Queensland, where my responsibilities included testing and inspection of the CP system.

Q3.
How have the ACA Training Scholarship and your role as Secretary of the YCG Committee influenced your professional growth and network expansion?

Being awarded the scholarship and serving as secretary have been invaluable for my professional growth. The scholarship provided access to specialised training and industry knowledge, while my role as secretary has expanded my organisational and leadership skills through coordination of meetings.

Q4.

What new skills, both technical and soft, have you developed since receiving the Denso ACA Training Scholarship?

I've expanded my technical skills in cathodic protection (CP). I completed the ACA Cathodic Protection Authorised Tester course in May, which deepened my understanding of the principles and practical applications involved in CP. The scholarship experience has also developed my communication skills and confidence, as I have been able to engage with industry professionals during my training.

Q5.

Have you undertaken any leadership roles or participated in significant remediation projects recently?

I have been heavily involved with the remediation of various university buildings, working on digital twin defect markups, conducting on-site condition investigation, and providing remedial recommendations.

Q6.

What feedback have you received from colleagues and clients about your work, and how has it shaped your approach to your career?

My colleagues often highlight my attention to detail and problem-solving skills, especially in report writing. From clients, I've received positive feedback on my commitment to safety during on-site works. This feedback has helped me build trusted client relationships and deliver results that reflect professionalism and integrity.

Q7.

Looking forward, what are your updated short-term and long-term goals in the corrosion prevention industry?

In the short term, I am focused on gaining further experience in the construction support area to deepen my technical understanding of concrete repair and cathodic protection. In the long term, I aim to contribute to industry standards and best practices by eventually writing a conference paper.

Coatings Technical Group

Applicators Technical Group

APPLICATORS ROADSHOW COATINGS 2025

Let's bring the industry together, raise awareness of **new technologies**, **product development**, maintain and develop new **Standards**, support **training opportunities** and more!

6th May	13th May	21st July	24th July
SYDNEY	**PERTH**	**AUCKLAND**	**CHRISTCHURCH**

Activities

- **Technical** Presentations
- Equipment **Demonstrations**
- Professional **Skills Development**
- **Forums** and Q&A sessions
- **Social** events
- **Training** opportunities

Price

Starting from $85 Only

Tickets on sale!

CLICK HERE TO GET YOUR TICKETS!

Time

8:00AM to 6:00PM **(All-day event)**

Major Sponsor

mcu coatings — best in corrosion protection

Supporting Sponsors

REMEDY ASSET PROTECTION

International — An AkzoNobel brand

CHESTERTON — Global Solutions, Local Service.

GANZ — GALVANIZING ASSOCIATION

APPLICATORS
ROADSHOW 2025
COATINGS

Sydney

06/05/2025

Time	Speaker	Topic
8:00 – 8:30	Bump in for exhibitors open	Trade tables are open
8:30 – 8:45	ACA	Registration
8:45 – 9:00	Justin Rigby – Coatings Technical Group	Welcome and Introduction
9:00 – 9:30	Johann Myburgh – MCU-Coatings	TBC
9:30 – 10:00	Arash Mansouri – Remedy Asset Protection	Limitations of Discontinuity (Holiday) Test on Concrete Coatings
10:00 – 10:30	Keith Owen – International Paint	Long term protection of Splash Zone - Marine Pilings with Protective Coatings
10:30 – 11:00 (Morning Tea)		
11:00 – 11:30	Aaron Williams – Heavy Minerals Limited	Abrasive Selection for Painting Contractors - A Review of Relevant Industry Standards, Specifications and Certifications
11:30 – 12:00	David Anderson - UCC	Field Applied Pipeline Coatings - What works where?
12:00 – 12:30	Ian Blevin – WOMA (Australia) Pty Ltd	Working Title "Industrial Maintenance Considerations for Hazardous Environments"
12:30 – 1:15 (Lunch)		
1:15 – 2:45 (OUTDOOR DEMONSTRATIONS)		
1:15 – 1:45	OUTDOOR DEMO Universal Corrosion Coatings	Application of a wide variety of pipeline coatings – Live demonstration
1:45 – 2:15	OUTDOOR DEMO Precision Laser Cleaning	TBC
2:15 – 2:45	OUTDOOR DEMO	TBC
2:45 – 3:15 (Afternoon Tea)		
3:15 – 3:45	Charlie Gooden - BlastOne International	Blasting at Long Distance. Corrosion Maintenance on the Sydney Harbour Bridge: a 30 Year Case Study
3:45 – 4:15	Ian Ellis – Metz Specialty Materials	Beyond Atmospheric Corrosion, Chemical protection in Industrial Areas
4:15 – 4:45	David Harrison – Galvanizers Association of Australia	AS 1397 ZM coatings in structural applications
4:45 – 5:00	Justin Rigby - Coatings Technical Group	Close & Farewell
5:00 – 5:30 (Networking Drinks)		

Tickets on sale!

CLICK HERE TO GET YOUR TICKET

Applicators Technical Group

Coatings Technical Group

APPLICATORS
ROADSHOW 2025
COATINGS

PERTH

13/05/2025

Time	Speaker	Topic
8:00 – 8:30	Bump in for exhibitors open	Trade tables are open
8:30 – 8:45	ACA	Registration
8:45 – 9:00	Justin Rigby – Coatings Technical Group	Welcome and Introduction
9:00 – 9:30	Johann Myburgh – MCU-Coatings	TBC
9:30 – 10:00	Amit Mehta - International Paint	TBC
10:00 – 10:30	David Anderson – Universal Corrosion Coatings	Field Applied Pipeline Coatings - What works where?
10:30 – 11:00 (Morning Tea)		
11:00 – 11:30	Mercy Baniasad – Metz Specialty Materials	Beyond Atmospheric Corrosion, Chemical protection in Industrial Areas
11:30 – 12:00	Pedram Mojarrad – Penetron Australia	Protection Against Biodeterioration & Acid Attack- Antimicrobial Admixture, Crystalline Waterproofing & Acid Resistant Coating
12:00 – 12:30	David Harrison – Galvanizers Association of Australia	AS 1397 ZM coatings in structural applications
12:30 – 1:15 (Lunch)		
1:15 – 2:45 (OUTDOOR DEMONSTRATIONS)		
1:15 – 1:45	OUTDOOR DEMO Universal Corrosion Coatings	Application of a wide variety of pipeline coatings – Live demonstration
1:45 – 2:15	OUTDOOR DEMO	TBC
2:15 – 2:45	OUTDOOR DEMO	TBC
2:45 – 3:15 (Afternoon Tea)		
3:15 – 3:45	Ian Blevin – WOMA (Australia) Pty Ltd	Working Title "Industrial Maintenance Considerations for Hazardous Environments"
3:45 – 4:15	Charlie Gooden – BlastOne International	Blasting at Long Distance. Corrosion Maintenance on the Sydney Harbour Bridge: a 30 Year Case Study
4:15 – 4:30	Justin Rigby – Coatings Technical Group	Close & Farewell
4:30 – 5:00 (Networking Drinks)		

Tickets on sale!

CLICK HERE TO GET YOUR TICKET

Applicators Technical Group

Coatings Technical Group

APPLICATORS
ROADSHOW 2025
COATINGS

AUCKLAND

21/07/2025

Time	Speaker	Topic
8:00 – 8:30	Bump in for exhibitors open	Trade tables are open
8:30 – 8:45	ACA	Registration
8:45 – 9:00	Tim Billing – Applicator Technical Group	Welcome and Introduction
9:00 – 9:30	Johann Myburgh – MCU-Coatings	TBC
9:30 – 10:00	David Harrison – Galvanizers Association of Australia	AS 1397 ZM coatings in structural applications
10:00 – 10:30	Eptec	TBC
10:30 – 11:00 (Morning Tea)		
11:00 – 11:30	Charlie Gooden – BlastOne International	Blasting at Long Distance. Corrosion Maintenance on the Sydney Harbour Bridge: a 30 Year Case Study
11:30 – 12:00	David Anderson – Universal Corrosion Coatings	Field Applied Pipeline Coatings - What works where?
12:00 – 12:30	Roger Hay – Engineering & Compressor Services Ltd	New Zealand Drillers Federation inc
12:30 – 1:15 (Lunch)		
1:15 – 2:45 (OUTDOOR DEMONSTRATIONS)		
1:15 – 1:45	OUTDOOR DEMO Universal Corrosion Coatings	Application of a wide variety of pipeline coatings – Live demonstration
1:45 – 2:15	OUTDOOR DEMO Precision Laser Cleaning	TBC
2:15 – 2:45	OUTDOOR DEMO	TBC
2:45 – 3:15 (Afternoon Tea)		
3:15 – 3:45		
3:45 – 4:15		
4:15 – 4:30	Tim Billing – Applicator Technical Group	Close & Farewell
4:30 – 5:00 (Networking Drinks)		

Tickets on sale!

CLICK HERE TO GET YOUR TICKET

Applicators Technical Group

Coatings Technical Group

APPLICATORS
ROADSHOW 2025
COATINGS

CHRISTCHURCH

24/07/2025

Time	Speaker	Topic
8:00 – 8:30	Bump in for exhibitors open	Trade tables are open
8:30 – 8:45	ACA	Registration
8:45 – 9:00	Tim Billing – Applicator Technical Group	Welcome and Introduction
9:00 – 9:30	Johann Myburgh – MCU-Coatings	TBC
9:30 – 10:00	David Harrison – Galvanizers Association of Australia	AS 1397 ZM coatings in structural applications
10:00 – 10:30	Eptec	TBC
10:30 – 11:00 (Morning Tea)		
11:00 – 11:30	Charlie Gooden – BlastOne International	Blasting at Long Distance. Corrosion Maintenance on the Sydney Harbour Bridge: a 30 Year Case Study
11:30 – 12:00	David Anderson – Universal Corrosion Coatings	Field Applied Pipeline Coatings - What works where?
12:00 – 12:30	Roger Hay – Engineering & Compressor Services Ltd	New Zealand Drillers Federation inc
12:30 – 1:15 (Lunch)		
1:15 – 2:45 (OUTDOOR DEMONSTRATIONS)		
1:15 – 1:45	OUTDOOR DEMO Universal Corrosion Coatings	Application of a wide variety of pipeline coatings – Live demonstration
1:45 – 2:15	OUTDOOR DEMO Precision Laser Cleaning	TBC
2:15 – 2:45	OUTDOOR DEMO	TBC
2:45 – 3:15 (Afternoon Tea)		
3:15 – 3:45	Jotun	TBC
3:45 – 4:15		
4:15 – 4:45		
4:45 – 5:00	Tim Billing – Applicator Technical Group	Close & Farewell
5:00 – 5:30 (Networking Drinks)		

Tickets on sale!

CLICK HERE TO GET YOUR TICKET

Applicators Technical Group

Coatings Technical Group

News from the ACA Foundation Chairman

Wayne Burns, Chair – ACA Foundation Limited

The ACA Foundation reflects the latent energy of a metal under a protective coating. Bursts of activity involve reaching out to present and past sponsors with insights into how their support has changed the lives of many budding corrosion practitioners. Emerging sponsors are approached as a sign of faith in our team and in the hope of a better world with greatly diminished corrosion, saving energy and creating new jobs.

We strive for improved understanding of our mission. We happily receive advice from our immediate and wider community members and are happy to welcome new faces as we strive for a more balanced gender balance.

The ACA Foundation's Purpose

The ACA Foundation is the charitable arm of the ACA, dedicated to advancing corrosion education and promoting corrosion control in the industry. The foundation is a not-for-profit entity. All donations generated by the Foundation are reinvested into the corrosion community through scholarships and educational programs to assist the next generation in this evolving and exciting industry.

ACAF 2025 Scholarship Applications - Applications for the 2025 series fo scholarships will be released in late May 2025. Please let all potential applicants know they should apply.

The New ACAF Board Restructured

The ACA Foundation Board has driven for a new and restructured format. This saw the addition of two new Directors in December 2024 (Geoff Will) and January 2025 (Brian Kaye). At the beginning of 2025, ACAF Board appointed directors with specific roles of responsibility. With that came the initiation of supporting committees of additional nominees. For all of the committee chairpersons, please visit our web site - www.corrosion.com.au/foundation/

It is with great acknowledgement that Maddie Huynh has joined our Sponsorship Funding Committee with Brian Kaye as Chair. Maddie has also been appointed as an Adjunct Director of the ACAF Board. Maddie brings a level of energy and young persons attitude that will assist our sponsorship team add additional focus on what the younger generation are looking for. Maddie was a recent recipient of an ACAF scholarship and has energetically provided a video interview that other future scholarship applicants will gain confidence in the benefits achievable as a young corrosion scientist.

Thank You to Long Standing Support of Sponsors

To the current sponsors and in collaboration with the Australasian Corrosion Association we are profoundly grateful for your generous donations, your support plays a pivotal role in the success of the foundations goals and provides a positive impact to our charitable organisation and the recipients of the awards.

Thank You to our Centurions

ACAF Director Willie Mandeno has been tireless in following up with existing Centurions in expediting their current year $100.00 donations. To all of our Centurions, thank you as your support also drives the annual scholarship programs. If you are not yet a Centurion donor, please visit our web site and submit your application or simply email wlmandeno@gmail.com

Become a member of an ACAF Board Committee

The many successful events delivered by ACAF only is a result of the work and great ideas generated by the ACAF committees. If you wish to assist please visit our web site or email ACAFoundation@corrosion.com.au

See you at the ACA Melbourne Conference in 2025

Melbourne is hosting the 2025 Corrosion conference, and the ACA Foundation Board & Committees look forward catching up and renewing acquaintances as well as awarding the 2025 Scholarships with our Scholarship Sponsors.

Cheers to our Corrosion Prevention & Asset Management Community.

Wayne Burns
ACA Foundation Chair

The sponsors of our 2024 Scholarships were;

Denso (Australia), Infracorr Consulting, Marine and Civil Maintenance, Phoenix Solutions, Universal Corrosion Coatings & the ACA Foundation Centurions.

Re-alkalisation is a Long-Term Solution for Carbonated Concrete

Dr Mohammad Ali, GHD Sydney
Former ACA President

Concrete re-alkalisation is a technique to restore alkalinity back to concrete. Note that alkalinity around reinforcement is required to keep reinforcement passive from corrosion; alkalinity can be lost due to concrete carbonation.

The re-alkalisation process involves placing metal (such as anode mesh or temporary reinforcement mesh) on concrete surface, spraying cellulous fibres (containing electrolyte) onto concrete surface, and connecting the structure reinforcement to the negative terminal of a direct current (DC) power unit and positive terminal (of the power unit) to the metallic mesh placed on the surface. Current is applied for typically 1-2 weeks, then undertake test to confirm if alkalinity is restored by measuring pH of concrete. Once pH of concrete is restored (to make reinforcement passive again), all setups on the structure are removed and no trace of re-alkalisation process is left behind on the surface.

Deterioration Free Girders in 2025 (Note: Dark spots on the girder seem to be wasp nests)

In circa 2001, I was involved in designing concrete re-aliksation for a bridge in Sydney, refer to photo 1 where the operator is spraying cellulous fibres to the bridge girders. Since the application of re-alkalisation in 2001, I have not heard back about deterioration of the girders treated. Out of interest, I took a photo from the riverbank (refer to photo 2) of the bridge as a passerby and found no damage to the bridge girders after 25 years of treatment.

As a professional, I am pleased to see the alkalisation technique has successfully fulfilled its purpose, with the bridge girders remaining defect-free for 25 years since its applicationc

An Operator Applying Re-alkalisation to the Bridge (Photo circa 2001)

PLENARY PAPER

Deterioration of Concrete Piles Underwater

P. Karajayli[1,*], S. Odlin[1], D. Cukierski[1]
[1]MEnD Consulting / Duratec Ltd, New South Wales, 2000, Australia
*Corresponding author email: phil.karajayli@duratec.com.au

Keywords:

piles, concrete, submerged, deterioration, sulfate

Abstract:

Reinforced and prestressed concrete piles submerged in marine or brackish waters are known to be subject to highly aggressive conditions. While it is well established that significant chloride contamination of the concrete cover, combined with intermittent wetting and high oxygen in the tidal/splash zone of the pile can often result in severe steel reinforcement corrosion and spalling, it is sometimes wrongly assumed that the submerged zone of the pile is in good condition without adequate confirmation. It has been reported that, in general, lower oxygen levels underwater typically limit the uniform corrosion rate of steel reinforcement in sound concrete, and this would appear to be the experience in most cases, however there are also limited reports of anaerobic corrosion and other deterioration mechanisms which can occur underwater, some of which can result in severe deterioration of the concrete and subsequently allow accelerated corrosion of the steel reinforcement. This paper explores typical risks of underwater deterioration and corrosion, requirements for underwater investigations and presents some case studies where underwater diving inspections revealed unexpected concrete deterioration underwater.

INTRODUCTION

Deterioration of reinforced concrete piles in the tidal and splash exposure zones of marine and brackish waters due to chloride-induced corrosion of steel reinforcement is a common and reasonably well understood mechanism that limits the service life of structures and often requires major maintenance intervention. Durability planning for new structures often involves understanding the different exposure zones of the structure, applying exposure classifications and designing accordingly using modern codes and/or durability modelling (which is typically based on time to corrosion) in order to achieve the required design life. While modern structure designs attempt to address potential durability issues to ensure the required design life is achieved, older structures were often not designed and constructed with this in mind. Many older structures are constructed in aggressive environments with poor quality concrete and poor quality construction that is susceptible to deterioration due to a variety of potential mechanisms.

The challenge for the asset manager is to understand the durability risks of existing structures, and this includes parts of the structure that are often hidden and cannot be easily investigated. There is often a trade-off between carrying out minimalist routine inspections and the cost to carry out out more detailed investigations which may uncover hidden deterioration.

The permanently submerged zone of concrete piles in marine and brackish waters presents such a challenge. While it is often assumed that the submerged zone of concrete piles is at low risk of steel reinforcement corrosion due to low oxygen levels and the risk of concrete deterioration appears to be a rare occurrence, there are examples of where this has been found to not be the case. This paper provides a discussion on the primary mechanisms encountered that may cause corrosion and deterioration in underwater concrete piles, with some relevant case-studies, and appropriate investigation methodologies that can be used to address some of these risks.

Literature Review

A primary outcome of the literature review confirmed there is very limited published technical literature and real-world case studies on this topic, particularly for piles in brackish waters. This is likely due to the difficulty in comprehensively inspecting piles underwater, the uncertainty on the condition underground which cannot be confirmed without excavation or exhumation of the pile, the potential corrosion mechanism (if present) being anaerobic corrosion which makes corrosion difficult to detect, and it would appear severe pile deterioration underwater remains a relatively rare occurrence. Given the lack of published information, further large-scale studies would be required to confirm this.

Corrosion Risks

When assessing the durability risk of concrete piles in marine and brackish water based on exposure zone, the primary consideration is justifiably most often given to the tidal and splash zones, where factors such as chloride contamination and intermittent wetting often result in severely corroded reinforcement causing concrete cracking and spalling. Much of the literature states or infers that there is generally a lower risk of steel reinforcement in the submerged zone.

In concrete structures in seawater or brackish water, chlorides diffuse into the concrete until eventually the depth of the steel reinforcement is reached. Once a threshold level of chloride concentration is met, chloride ions attacking the passive layer protecting the steel may allow the corrosion process to proceed, subject to several variables [1]. The exposure condition of the concrete, primarily the height relative to the mean water level, has an effect on the depth of penetration of chloride ions. The highest surface concentrations occur at relatively high position (atmospheric zone), where the accumulating effect of drying out will be strong. At lower positions (tidal and splash zones), the concrete is wetter and transport towards the inner parts will be faster and consequently the penetration will be deepest. In the submerged part, accumulation due to wetting and drying is absent; here, equilibrium between bound and free chloride governs the total chloride content, together with relatively fast transport to the inner parts [2].

The submerged zone of the piles may not be adequately accounted for during inspections, due to assumptions that the condition of the concrete in the submerged zone is good [3], or to the difficulty inherent in accessing, cleaning, and inspecting concrete underwater [4]. As the concrete is fully saturated with water, the diffusivity of oxygen is reduced and thus also the availability of oxygen at the surface of the embedded steel which lowers the steel potential (reducing likelihood of corrosion initiation) and, should initiation occur, supresses the corrosion rate [2], [3], [5]. This can result in instances where high concentrations of chlorides (generally considered to be above 1.0% concentration by weight of cement [1]) are present in concrete and yet limited uniform reinforcement corrosion occurs.

The rate of corrosion of steel within good quality, well-compacted, dense, and uncracked concrete with good cover to the steel and low permeability, even with chloride contamination, can also remain low due to the protection provided by the high pH environment of the concrete forming a passive layer on the steel and continuing to provide alkaline buffering [6]. For older structures with poorer quality concrete this is often not the case, and in instances where reinforcement becomes exposed underwater, such as in a location where concrete is cracked, or the concrete is deteriorated, macrocell corrosion effects may occur[2].

Macrocell corrosion is typically seen as localised corrosion (rather than uniform corrosion) with a separation of the anodic reaction and the cathodic reaction between two separate areas [1]. When a macrocell forms, anodic areas experience accelerated corrosion rates while the passivity of cathodic areas is stabilised. For submerged structures, this may occur where reinforcement is not entirely embedded in concrete, caused by a difference in potential between steel embedded in concrete and the exposed steel, and may be exacerbated by direct exposure to chloride-rich water [2].

Corrosion of steel reinforcement in oxygen-deprived areas (which is the case for submerged areas of piles) is known as anaerobic corrosion and often referred to as "black rust" (magnetite, Fe3O4). The identification of anaerobic corrosion or "black rust" in structures is typically very difficult, as unlike "red rust" resulting from aerobic corrosion (ferric oxide, Fe2O3), it does not cause expansive forces to be applied to the concrete and therefore usually does not cause concrete defects such as cracking, spalling or delamination. Studies have postulated that black rust occurs under the conditions that the anode and cathode are separated (by at least a few hundred millimeters) and in low oxygen conditions. When these conditions are satisfied, the iron at the anode may stay in solution, rather than forming Fe2O3 [1].

While not commonly observed, black rust has been found in areas with limited oxygen concentration, such as under damaged waterproofing membranes [1], in the submerged portion of concrete piles [3], in culverts [7], and in reinforced concrete elements where corrosion was at an advanced stage, cutting oxygen off from the uncorroded central portion of the rebar [8].

A study of 3 out-of-service bridges in Florida in a marine environment aged between 51 to 66 years old examined sample piles that were exhumed [3]. Interestingly, the study found that for the most part the steel reinforcement was in good condition as expected, however there were areas of localised severe corrosion of between 1-12% of the length of steel examined that had appreciable section-loss of steel of 20-29%. It is noted that the concrete used for these older bridges would likely have been highly permeable and much lower quality than modern concrete mixes. The study hypothesises that that cathodic reaction rates under oxygen diffusional limitation that are negligible in cases of uniform corrosion can nevertheless support substantial corrosion rates if the corrosion becomes localised. In addition to oxygen limitation, the study also notes that corrosion in the submerged zone can be somewhat suppressed by galvanic coupling with reinforcing steel in the tidal and splash/evaporation zones which started corroding earlier in the life of the structure. This coupling tends to make the potential of the submerged steel more negative, and this effectively elevates the corrosion threshold and thereby retards the initiation of corrosion below water (a form of cathodic prevention). However, the effect of the small but finite cathodic reaction taking place on the entire submerged region (plus any additional coupling to cathodic regions above water) can be enough to sustain appreciable anodic activity over small regions. The study proposes a steady-state predictive model for this scenario and projects that eliminating corrosion in the splash/evaporation zone could in some cases increase corrosion vulnerability of steel in the submerged region, as the above-water region could then act as a supplemental cathode to the underwater area.

While the Florida study presents some potentially serious concerns and challenges to the asset manager, it is only based on a very small sample size. This issue of anaerobic corrosion on piles is largely unreported in Australia, but this may be because there is limited opportunity to perform such destructive investigations unless a pile is being removed from service. In addition, the risk-based structural implications of localised corrosion would need to be assessed on a case-by-case basis. Further investigation into this issue is required to understand the real-world risks.

Concrete Durability Risks

There are various mechanisms by which concrete can deteriorate underwater in marine/brackish environments. Concrete deterioration may have structural implications such as loss of strength and loss of concrete section. While concrete deterioration underwater may not be typically caused by steel reinforcement corrosion, degradation of the concrete cover can eventually directly expose steel reinforcement/strands to the chloride-rich water and allow corrosion to occur, further weakening the pile.

Publications such as ACI 201.2R-16 *Guide to Durable Concrete*, ACI 546.2R *Guide to Underwater Repair of Concrete*, and BRE Special Digest 1 *Concrete in Aggressive Ground* provide a good summary of the primary risks to durability of concrete in water and soil. In addition to steel reinforcement corrosion risks, the primary durability risks to piles underwater in natural waterways typically include:

- Deficient construction practices and errors
- Sulfate attack – conventional and thaumasite
- Alkali Silica Reaction (ASR)
- Delayed Ettringite Formation (DEF)
- Acid attack
- Leaching
- Industrial chemical attack
- Mechanical damage – impact, abrasion and cavitation
- Damage due to loads
- Freezing and thawing – although not typically an issue in most regions of Australia

As this paper focuses on piles in natural waterways, other potential concrete deterioration mechanisms are not discussed, such as acid attack from acid-producing bacteria as found in sewers.

Sulfate attack is a mechanism which may result in deterioration of the concrete causing both chemical and physical attack of the concrete. Concrete is typically exposed to sulfates from exposure to soil and water with high sulfate concentrations. The mechanism by which conventional sulfate attack occurs is that the sulfate ions react with calcium hydroxide within the cement to form gypsum, and with calcium aluminates to form ettringite, the growth of which causes expansive pressure on the concrete resulting in cracking/failure of the concrete [9]. Other types of sulfate attack (such as thaumasite sulfate attack) may occur under specific environmental conditions.

The aggressivity of the sulfate attack also depends on which cation accompanies the sulfates. Magnesium sulfate is a particularly aggressive species. In chloride containing water (i.e. seawater or brackish water), the risk of sulfate attack can be reduced by the presence of chloride ions. AS 5100.5 section 4.8.2 [10] states that "sulfate ions become aggressive at levels of 600 to 1000 ppm when combined with magnesium or ammonium ions. In the presence of chloride ions, however, attack by sulfate ions generally exhibits little disruptive expansion" and "if magnesium ions exceed 1000 mg/L together with sulfate ions (SO4) more than 1000 ppm in soil or 400 ppm in ground water, an aggressivity or exposure classification of one higher class should be adopted, additional protective measures should be considered and expert advice should be sought".

The combined attack of magnesium and sulfate in seawater or brackish water occurs when the magnesium and sulfate ions react with portlandite and aluminate phases in hardened concrete to form gypsum (CaSO4 · H2O) and brucite (Mg[OH]2), the combination of which can be diagnostic of its occurrence.

The formation of gypsum can be catastrophic for hardened concrete due to its two-fold deterioration potential:

- Gypsum growth is an expansive reaction which can result in physical cracking of the paste and aggregate, exposing unreacted paste to the system which will allow for further deterioration.

- Gypsum is soft and non-durable, such that cement paste that has been replaced by gypsum will have a greatly reduced compressive strength and can be easily worn away/removed by even the slightest physical abrasion.

Unlike gypsum, the formation of brucite (often coupled with aragonite (Ca[CO]3)) can form a somewhat protective barrier to prevent further deterioration. However, this quasi-protective layer can be removed by physical abrasion or deterioration of the underlying concrete [2].

Alkali-Silica reaction (ASR) is a mechanism which occurs as a result of a reaction with certain types of aggregates that are susceptible to ASR within the concrete mix. The ASR Field Identification Handbook defines ASR as a chemical reaction between the alkali hydroxides in the pore solution of concrete and certain forms of reactive silica minerals occurring in some aggregates. The reaction product, an alkali-silica gel, is hygroscopic, and will absorb water and swell if the concrete is in a moist environment [11]. ASR requires high levels of moisture to occur, and thus is susceptible to form in submerged structures which contain reactive aggregates. The significance is that deleterious expansion can cause cracking (exposing the reinforcement/strands directly to chloride-rich water and allowing corrosion to occur) and reducing tensile strength of the concrete.

Delayed Ettringite Formation (DEF) can occur when under certain conditions, such as concrete elements exposed to high temperatures during curing, and later exposed to moisture, which can result in expansion and cracking. Modern codes have limitations on the curing temperature, which is particularly important when steam-curing is used. Submerged areas of structures may be susceptible to this form of deterioration, and therefore signs of cracking should be investigated petrographically to confirm whether DEF or ASR is the cause. In two of the case studies detailed below, deteriorated concrete attributed to ASR and DEF was identified in prestressed concrete piles, primarily in the tidal zone and below [12], [13].

Acid attack of concrete (which may be combined with sulfate attack) may occur in certain conditions such as natural waters with low pH and in acid-sulfate soils (ASS). While durability planning for the design of new structures typically attempts to address this issue through compliance with codes and guidelines (e.g. AS5100.5, TfNSW TS 02014 Provisions for Concrete Structures in Acid Sulfate Soils), it is largely unknown what effect ASS is having on older structures with potentially poorer quality concrete that have been exposed to this environment over the long term.

Other less common types of deterioration can occur in certain conditions such as leaching of cement compounds in poor quality concrete with high water flow resulting in a weakening the concrete, and attack by aggressive industrial agents (such as ammonia) in contaminated soils and water.

Investigations

It is prudent that a comprehensive condition investigation includes an assessment of potential deterioration mechanisms based on exposure conditions.

It is typical practice to carry out periodic routine underwater visual inspections using divers or remote-operated vehicles (ROVs) to check for any obvious defects. This inspection should first involve cleaning of a representative sample of piles as marine growth could mask potential hidden issues. Road authorities in Australia generally have underwater inspection procedures which outline the frequency, level of detail, and proportion of piles to be examined on bridge piles. The Ports Australia Wharf Structures Condition Assessment manual (WSCAM) also provides some guidance on underwater inspections.

Piles should be cleaned to remove marine growth, which is typically completed using a combination of hand scraping and high-pressure water blasting, where high pressure water blasting will achieve better results and is best used for detailed pile examination. After cleaning, visual inspection should be completed by divers under supervision of an engineer with sufficient experience to interpret the results of the inspections and direct the diver should any unusual features be encountered. The results of the inspection should be recorded in a logical manner so that the location (pile face/cardinal direction and depth), dimensions, and type of defects are recorded.

If any unexpected or significant deterioration has occurred, consideration should be given to further testing. Petrographic examination of core samples in accordance with ASTM C856 is an ideal technique for identifying potential deterioration mechanisms. Concrete petrography is a technique which involves examination of polished sections and thin sections of concrete using microscopes to provide insights into the mineralogical, chemical and microstructural features of concrete. Petrography may be used to identify and confirm the presence of a number of concrete deterioration mechanisms including ASR, DEF, leaching, sulfate attack and acid attack. This may also be complemented by other laboratory techniques such as X-ray Diffraction (XRD) or X-ray Fluorescence (XRF).

Core sampling underwater can be difficult in practice however, as there is a risk of cutting through steel reinforcement / pre-stressed strands, and it may not be appropriate to carry out (particularly for pre-stressed piles).

The condition of the buried part of piles is an unknown factor and is also difficult to examine. A risk-based approach should be used in making this assessment. If safe to do so, consideration may be given to various investigative methods. Testing of the soil and water aggressivity can provide an indirect indication of potential issues (noting that aggressivity can change over time), combined with understanding the age of the structure. Localised shallow excavation around the pile (if structurally safe to do so) may provide an indication of potential deterioration in the buried zone. In addition, testing the concrete quality above the buried area may provide an indication of the likely durability below-ground.

CASE STUDIES

Four case studies where unexpected levels of concrete deterioration in the submerged zone were identified during underwater dive inspections are discussed in this section.

1 *TEMPE BRIDGE, SYDNEY*

A major bridge over the Cooks River in Tempe (Tempe Bridge) which is part of the Princes Highway, built in 1960, was found to have severely deteriorated piles during an underwater inspection in 2002 [13]. The precast octagonal piles were visually obstructed by concrete skirts, which prevented inspection during low tide, therefore preventing the section loss from being flagged earlier during routine visual inspections.

Some of the pile concrete was found to be completed disintegrated in the outer annulus, up to the depth of the pile reinforcement (approximately 60 mm depth), shown in Figure 7. Beyond this, the concrete was found to be deteriorated, cracked, and weak, increasing in strength towards the centre of the pile. The cause of the deterioration was believed to be AAR or DEF. Urgent actions including restricted load limits and strengthening works were required to avoid potential catastrophic failure of the bridge.

The bridge was rehabilitated in two stages. In Stage 1, additional cast-in-place bored piles were constructed adjacent to the existing piers. A steel underpinning system was used to jack up the pier substructure and transfer the loads to the new piles. In the Stage 2, a new prestressed concrete pile cap was constructed around the underpinning system and existing piers, which was used to both provide durability corrosion protection to the exposed steel, and to integrate the existing bridge substructure with the Stage 1 remedial works.

Figure 7: Pile concrete deterioration in brackish water attributed to ASR or DEF.

2 BRIDGE IN NEW SOUTH WALES

The second case study covers a small reinforced concrete bridge in NSW. The bridge was constructed approximately 60 years ago, with piles constructed from pre-cast prestressed concrete, driven into a tidal creek with brackish water.

Investigation Methodology

Reinforced concrete piles were cleaned of marine growth and visually inspected for defects below and above-water. While the piles were in good condition above-water, including the tidal/splash zone, the inspection revealed loss of concrete section underwater. Materials testing was then completed on two concrete samples: the first collected from the tidal zone in a sound concrete area (as a reference), and the second sample collected from a deteriorated pile in the submerged zone. Testing was carried out for chloride content profiles, sulfate content profiles, petrographic examination, X-ray Diffraction (XRD), X-ray Fluorescence (XRF), and compressive strength testing.

Preliminary water and soil aggressivity testing were also conducted on a water sample taken at the turn of an outgoing tide, and of the topsoil layer near deteriorated piles.

FINDINGS

The dive inspections highlighted the presence of concrete section loss on the underwater portions of some piles, including the identification of large areas of concrete loss and cracking. The condition of the piles was obscured by thick marine growth which is likely why the deterioration had gone unnoticed. The extent of concrete section loss was not uniform across all piles. Some of the piles had reduction in concrete cross-sectional area at the most deteriorated portion of the pile (Figure 1), while no section loss was observed in the pile in the best condition, however softening of the cement paste causing aggregate to become exposed was observed (Figure 2). Spiral reinforcement had been exposed due to the deteriorated concrete on the pile in the poorest condition, allowing corrosion of the reinforcement to occur.

A concrete sample was retrieved from the pile in the poorest condition. The concrete was weak and friable, allowing the sample to be retrieved by hand. Figure 3 shows an image of a cut section of the sample taken in the laboratory after drying, including cracking through a piece of aggregate.

Figure 1 (top): Concrete deterioration on underwater piles.

Figure 2 (bottom): Concrete pile at same bridge with no section loss.

Figure 3: Cross section of sample collected from deteriorated pile.

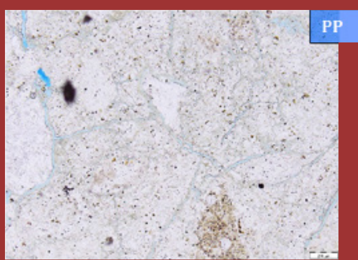
Petrographic analysis indicated that the entire thickness of the sample, around 40 mm, was found to have been replaced by gypsum (Figure 4). In addition, voids and microcracks were filled with gypsum and the paste was soft and powdery throughout. Another petrographic texture identified in the above water sample was popcorn-calcite deposition (PCD). PCD is deposit which forms in cement paste that is depleted of residual cement. It typically occurs in concrete with a reduced pH, exposure to moisture ingress and can be (but not always) associated with mechanisms like ASR and specific types of sulfate attack. Concrete with this deposit has typically been decalcified and exhibits weaker, more friable characteristics compared to non-impacted concrete.

The samples were also petrographically examined for signs of ASR. The aggregate fractions of the samples had ASR potential per HB 79. However, evidence of ASR was not identified in either of the samples, and the condition of the piles in the tidal and atmospheric regions showed no evidence of ASR cracking. Therefore, ASR was considered unlikely as a potential cause of the concrete deterioration.

Analysis by X-ray Diffraction (XRD) confirmed the presence of brucite in the sample. Evidence of similar attack was not identified on the sample collected in the tidal zone of the piles. Both gypsum and brucite were identified via XRD.

Petrography also confirmed that the concrete only contained Portland cement, and no supplementary cementitious materials (SCMs) were identified. The design strength was nominated as 38MPa. This could not be confirmed by core sampling due to the very high congestion of embedded steel. For new bridges, AS5100.5 requires SCMs to be used in the concrete mix to enhance the durability of concrete to achieve the required design life.

Water testing of a sample collected from the creek did not highlight any particularly high concentrations of sulfates (1,700 mg/L), chlorides (13,000 mg/L), or magnesium (820 mg/L), the levels of which were not found to be greater than that typically found in seawater. However, ion concentrations are expected to vary over time, and this was a single test at a point in time. It is also possible that historic uses of the land around the creek may have contributed to high sulfate levels in the past. The water flow of the creek is relatively fast due to the tidal effect and it was noted that the pile in worst condition is facing downstream. Based on the limited test samples carried out and the petrographic and XRD findings, the cause of deterioration was most likely caused by the combined attack of sulfates and magnesium from exposure to the creek water.



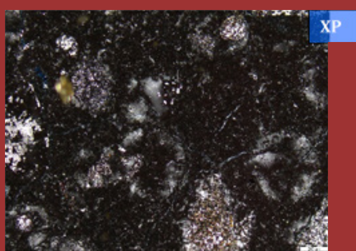


Figure 4: Area of sb-p1p5 that had been completely replaced by gypsum, same field of view, note the absence of gp.

3 RAWDON ISLAND BRIDGE, NSW

In 2021 flooding events prompted dive inspections to be conducted on Rawdon Island Bridge, which spans the Hastings River in Sancrox, NSW. The Bridge was constructed around 63 years ago. The bridge piles are reinforced concrete which were anchored into bed rock and cast in-situ and are exposed to tidal brackish river water.

The dive inspection uncovered significant loss of section of the reinforced concrete piles, in one case a 90% reduction in section was observed, as seen in Figure 5 [14]. Generally, the piles in the deepest part of the river were the most affected. Where steel reinforcement was exposed, generally section loss of the rebar was also observed.

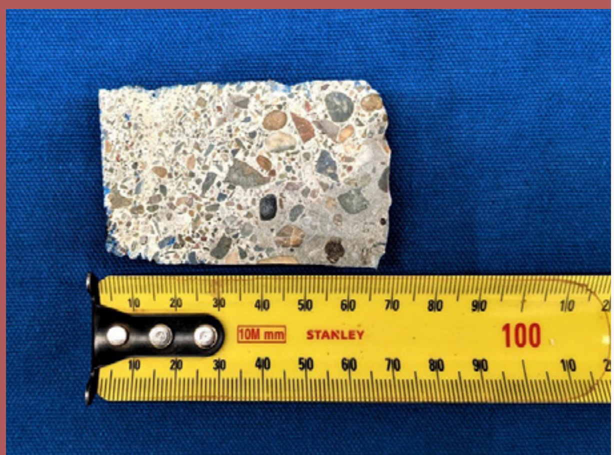
A soft white residue was found near the deteriorated areas of the piles, and concrete core samples were examined petrographically and via XRD techniques. Figure 6 shows a cross section of one of the core samples taken from the piles and the change in the cement paste morphology as sample depth increased. The white residue was found to be an amorphous material, thought to have formed due to excessive leaching of the calcium bearing phases in the concrete.

Directly beneath the amorphous residue, the cement paste in the cores was usually completely leached of portlandite and lacking in residual cement. In some cases, the cement paste had minor amounts of another phase present (likely ettringite or gypsum). The section shown in Figure 6 had cracks that were filled with ettringite that passed through aggregate particles, indicative of sulfate attack, however attack by sulfates was deemed unlikely to be the cause of deterioration, due to the low sulfate content measured in the concrete.

The type of cement or presence of SCMs could not be identified as the portlandite had largely leached out. The compressive strength of the concrete (as tested in conformance to AS1012.14) was found to be an average of 42MPa.

Concrete that is exposed to water migration while in service is at risk of being leached. Leached concrete can be depleted of calcium-bearing phases that are critical to its integrity, leaving behind a husk of weak, softer material. The degree of leaching (or more severe degradation and material loss) is dependent on numerous factors including pH, dissolved salts content/chemistry, suspended load and more. Excessive leaching of the portlandite and Portland cement phases was determined to be the cause of concrete deterioration.

Pile repairs were carried out by encasement of the original pile with micropiles drilled into the surrounding riverbed.



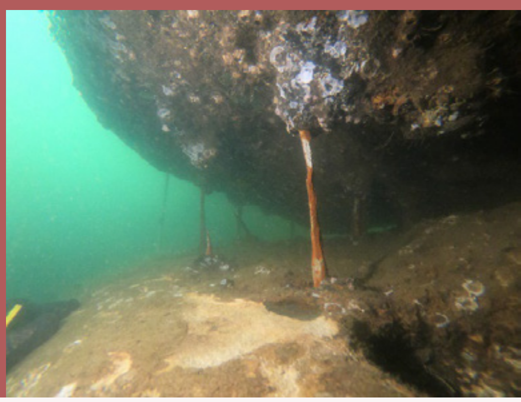


Figure 5 (top): Pile with 90% section loss at Rawdon Island Bridge.

Figure 6 (bottom): Cross section of core sample from pile at Rawdon Island Bridge.

4 TWO BRIDGES IN THE SOUTH ISLAND OF NEW ZEALAND

In 2000 in the South Island of New Zealand, piles from two bridges constructed in 1969 were found to have cracking, splitting, and spalling on a quarter to a third of bridge piles [12].

The piles were of prestressed concrete and were submerged in brackish water with tidal movement. The piles were generally in good condition above the high tide level, and cracking was observed to extend from the tidal zone to below low tide level and sometimes below bed level, with softened concrete. The paper notes that the same aggregate was used in both bridges, though the piles were manufactured by different suppliers. The design compressive strength was 45 MPa for one of the bridges, and cement content was measured at around 320 kg/m3.

In total, thirteen concrete samples were collected across both bridges. ASR was conclusively identified in 2 samples and was identified as a possible deterioration mechanism in cores from all other piles (6 samples). DEF was identified in 2 samples, and those 2 samples were identified in cores showing signs of ASR, both of which were also located within the tidal zone. Crack patterns observed by microscope showed that the concrete was subjected to expansive stress, consistent with ASR-induced DEF occurring in permanently wet concrete. There was some difficulty in diagnosing the cause of the deterioration observed on the piles, as evidence of ASR and DEF were not conclusively identified in all samples, despite targeting concrete sampling in areas showing deterioration.

CONCLUSIONS

This paper has discussed the various typical mechanisms by which concrete piles underwater in marine and brackish water may be subject to corrosion of steel reinforcement and deterioration of the concrete. While corrosion of steel reinforcement in concrete underwater is mostly inhibited by limited oxygen, there have been limited reports overseas that anaerobic corrosion can occur at localised locations. With respect to concrete deterioration, depending on the specific site location, exposure and concrete quality, this can include such effects as external attack (such as from sulfates in combination with magnesium ions and acidic water/soil), or internal attack such as from ASR and DEF. Deterioration of the concrete if left unchecked can then result in exposure of the steel reinforcement/strands to the environment and allow corrosion to occur.

To address this largely hidden risk, it is prudent to implement regular routine inspections which should include representative marine growth cleaning and underwater visual inspection, followed by more detailed testing and sampling if deterioration is observed. Techniques such as petrographic examination and XRD are ideally suited for identifying potential causes of deterioration combined with understanding the exposure condition and aggressivity of the soil and water.

While it is outside the scope of this paper to discuss remedial options for deteriorated underwater piles in detail, there are various techniques which have been employed. The type of repair selected will need to address the root cause of the issue to ensure adequate extension of service life and that the problem is not simply being masked. Typical repair details may include patch repair and pile encasements (reinforced or unreinforced) combined with cathodic protection to arrest corrosion if adequate electrical continuity is present. In extreme cases of deterioration, new piles may need to be constructed.

While concrete deterioration can usually be visually observed, the hidden risk of anaerobic corrosion of steel reinforcement in piles underwater is not well understood and there is very limited published data on this topic, particularly in Australia. Further investigation into this topic, including a risk-based assessment of potential structural implications is required for asset managers to make informed decisions. This would ideally involve detailed destructive investigations of piles of older bridges that are demolished in the future when the opportunity arises.

REFERENCES

[1] J. P. Broomfield, Corrosion of Steel in Concrete, 2nd ed., Oxon: Taylor & Francis, 2007, pp. 9-10.

[2] L. Bertolini, B. Elsener, P. Pedeferri and R. P. Polder, Corrosion of Steel in Concrete, Weinheim: WILEY-VCH, 2004.

[3] M. T. Walsh, Corrosion of Steel in Submerged Concrete, Florida, 2015.

[4] ACI Committee 546, "Guide to Underwater Repair of Concrete," American Concrete Institute, 1998.

[5] Standards Australia, HB84, Guide to Concrete Repair and Protection, 2018.

[6] R. E. Melchers, "Field Experience and the Long Term Durability of Reinforced Concrete Structures," in International Conference on Performance-based and Life-cycle Structural Engineering, Brisbane, QLD, 2015.

[7] H. Fatemi, M. Moore and R. Khatri, "Importance of Detection of Black Rust Formation," in Austroads Bridge Conference, 8th, 2011, Sydney, NSW, 2011.

[8] R. O'Donovan, B. D. O'Rourke, K. D. Ruane and J. J. Murphy, "Anaerobic Corrosion of Reinforcement," Key Engineering Materials, Vols. 569-570, 2013.

[9] BRE Construction Division, BRE Special Digest 1:2005, BRE Bookshop, 2005.

[10] Standards Australia, AS 5100.5 Bridge Design Part 5: Concrete, 2017.

[11] M. Thomas, B. Fournier, K. Folliard and Y. Resendez, "Alkali-Silica Reactivity Field Identification Handbook," U.S. Department of Transportation, 2011.

[12] S. M. Bruce, S. A. Freitag, A. Shayan, R. Slaughter and R. Pearson, "Identifying the cause of concrete degradation in prestressed bridge piles," in Corrosion & Prevention 2008, 2008.

[13] Y. C. Chong, L. Prasad, S. Deshpande, H. Madrio and M. Ali, "Bridge over Cooks River at Tempe," in AustRoads Bridge Conference, 2022.

[14] J. Duffy, G. Deutsch and L. Holloway, "Case Study - Rawdon Island Bridge Remediation Project," in Concrete Institute of Australia, Concrete 2023, 2023.

[15] A. B. Poole and I. Sims, Concrete Petrography: A Handbook of Investigative Techniques, Second Edition ed., Boca Raton, Florida: CRC Press, 2016.

AUTHOR DETAILS

P. Karajayli is the corresponding author of this paper. He is a Technical Director at MEnD Consulting/Duratec Ltd and a chartered engineer with more than 23 years' experience specialising in infrastructure condition assessments, durability, repair and protection, corrosion management, cathodic protection design and life-cycle maintenance planning.

His industry experience spans across a wide range of infrastructure including bridges, tunnels, marine, rail, water and wastewater assets with experience in both consulting and remedial contracting.

S. Odlin is a Consulting Engineer at MEnD Consulting/Duratec Limited, a position she has held since 2022. She is responsible for conducting inspection and condition assessment of structures and providing durability advice to extend their life.

D. Cukierski is the Laboratory Manager at MEnD Consulting/Duratec Limited. With over 10 years of experience, he specialises in the forensic and compositional analysis of concrete and other materials utilising optical petrography, X-ray diffraction, scanning electron microscopy, wet chemistry and other methodologies.

2025 Training Calendar

AMPP Coating Inspector Program Level 1	
WA - Perth	05-10 May 2025
SA - Adelaide	16-21 Jun 2025
NZ - Auckland	07-12 Jul 2025
NZ - Christchurch	28 Jul-02 Aug 2025
WA - Perth	04-09 Aug 2025
NSW - Sydney	18-23 Aug 2025
NSW - Newcastle	29 Sep-04 Oct 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	12-16 May 2025
SA - Adelaide	23-27 Jun 2025
NZ - Auckland	14-18 Jul 2025
WA - Perth	11-15 Aug 2025
NSW - Sydney	25-29 Aug 2025
NSW - Newcastle	06-10 Oct 2025
QLD - Brisbane	20-24 Oct 2025
VIC - Melbourne	24-28 Nov 2025

AMPP Cathodic Protection Level 1 Tester	
VIC - Melbourne	03-07 Feb 2025
QLD - Brisbane	12-16 May 2025
WA - Perth	07-11 Jul 2025

AMPP Cathodic Protection Level 2 Technician	
QLD - Brisbane	19-23 May 2025
WA - Perth	14-18 Jul 2025

AMPP Cathodic Protection Level 3 Technologist	
Online/AEST	28 Apr-02 May 2025

AMPP Cathodic Protection Level 4 Specialist	
Online/AEST	05-09 May 2025

ACA Corrosion Technology Course	
VIC - Melbourne	02-06 Jun 2025
NSW - Sydney	01-05 Dec 2025

ACA Coating Selection and Specification	
Online/AEST	05-07 May 2025

ACA GAA Hot Dip Galvanizing Inspector Program	
WA - Perth	08-09 Apr 2025

AMPP Corrosion Under Insulation	
Online/AEST	02-06 Jun 2025

AMPP Concrete Coating Inspector	
VIC - Melbourne	30 Jun-04 Jul 2025

ACA ACRA Concrete Structures and Buildings	
Online/AEST	17-18 Mar 2025
Online/AEST	15-16 Sept 2025

AMPP Craftworker Series (CWS) C6/C7/C12	
SA - Adelaide	19-24 May 2025
SA - Adelaide	15-20 Sep 2025

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

Course Spotlight:
ACA ACRA Corrosion & Protection of Concrete Structures & Buildings

More information & Registration

Overview:

This course is a partnered delivery between ACRA and the ACA to provide essential training for Asset Managers, Port Engineers, Bridge Maintenance Managers, Building Managers, Heritage Structure Engineers, Plant Engineers, Consulting Engineers, Architects, Specialist Contractors, Construction Material Suppliers, Asset Condition Inspectors and Overseers.

The ACA ACRA Corrosion & Protection of Concrete Structures & Buildings course provides an understanding of the mechanisms of the corrosion, protection, and repair of reinforced concrete structures and buildings.

Who should attend

Asset, Bridge and Building Managers, Engineers, Architects, Contractors, Suppliers, Inspectors and Overseers.

Course highlights:

- The Characteristics of Cement and Concrete
- Concrete Deterioration Mechanisms
- Corrosion of Reinforcement in Concrete
- Survey and Diagnosis of Concrete – On-site Measurements and Laboratory Measurements
- Repair and Protection of Reinforced Concrete – Mechanical Methods, Cathodic Protection and Further Electrochemical Methods & Permanent Corrosion
- Preventative Measures for New Concrete

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.	✓	✓	✓	✓	✓	✓
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	✓	✗	✗	✗	✗	✗