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CORROSION
& MATERIALS

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CONCRETE AND C&P2016 FEATURE

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Corrosion & Materials
Corrosion & Materials is the official publication of The Australasian Corrosion Association Inc (ACA). Published quarterly, *Corrosion & Materials* has a distribution of 2,500 to ACA members and other interested parties. Each issue features a range of news, information, articles, profiles and peer reviewed technical papers. *Corrosion & Materials* publishes original, previously unpublished papers under the categories 'Research' and 'Professional Practice'. All papers are peer reviewed by at least two anonymous referees prior to publication and qualify for inclusion in the list which an author and his or her institution can submit for the ARC 'Excellence in Research Australia' list of recognised research publications. Please refer to the Author Guidelines at www.corrosion.com.au before you submit a paper to Tracey Winn at twinn@corrosion.com.au

ACA also welcomes short articles (technical notes, practical pieces, project profiles, etc.) between 500 – 1,500 words with high resolution photos for editorial review. Please refer to the Article Guidelines at www.corrosion.com.au before you submit a short article to Tracey Winn at twinn@corrosion.com.au

The Australasian Corrosion Association Inc
The ACA is a not-for-profit, membership Association which disseminates information on corrosion and its prevention or control by providing training, seminars, conferences, publications and other activities.

Front Cover Photo: Geraldton concrete silo remediation project (WA) completed by Freyssinet Australia
Photo courtesy Freyssinet Australia.

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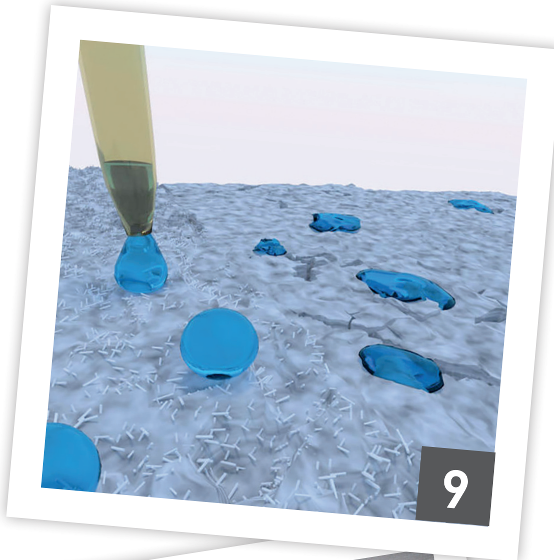

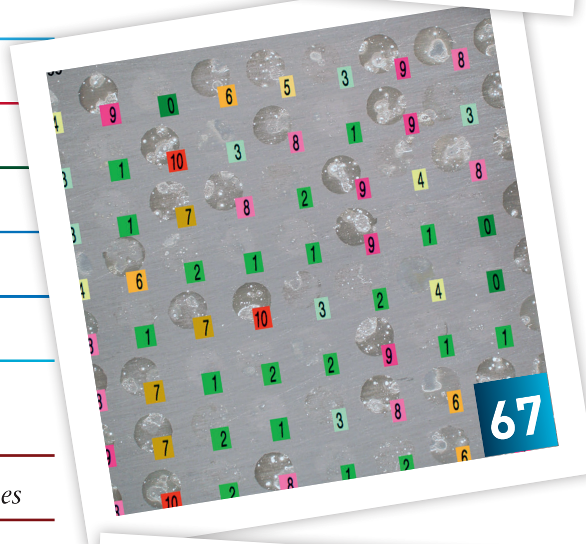

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John Duncan
President

It scarcely seems a year since the Conference in Adelaide, yet here we are again on the eve of the Auckland conference. My perception is that the planning of this has gone well, and I look forward to seeing many of you again at the conference. Our ACA conferences are an important element in our information-sharing business – as much in the gaps between papers as in the papers themselves, and briefly bringing a much wider set of knowledge to the host city than is available to any local Branch. So the decision which the Board sought feedback on from the Branches regarding circulation of our conferences is an important one. I gather that the feedback was so widely varying that, for the moment at least, the status quo will probably be retained. Perhaps the first thing that needs to be mutually agreed is the purpose of the Annual ACA Conference.

As a consequence of the rough times in parts of the Australian industry, we are looking at a down-turn in membership numbers over the last year, after a number of years of gains. The membership survey, high-level results from which were outlined in the last *Corrosion & Materials*, should provide all of us with understanding how we might reverse the loss of members again, once the economy stabilises.

You will have seen in the electronic bulletin *Corrosion Matters* that the revised Strategic Plan is close to being adopted by the Board. Thank you to those members who participated in the workshop with the Board to develop it. There are some exciting possibilities in partnering with others, including liaison with the European Federation of Corrosion as well as our traditional avenues with NACE, to extend the value of ACA's training schemes, and initiatives to raise the profile of ACA with decision-makers in government and asset management circles. The revised Plan should help us to focus our activities in these areas. This revised Strategic Plan will be discussed more fully with the Council at its meeting in Auckland, so that all Branches can understand the directions in which the Board sees ACA heading.

I have been privileged to receive briefings at intervals from Dean Wall, the Board Chair, who will be reporting to the Council meeting on behalf of the Board on the progress over the last year. I understand that the new appointments to the Board, Di Brookman and Chris Badger, have contributed well to the Board deliberations. Their backgrounds were discussed in the last Corrosion and Materials issue, and they each bring important additional skills to the ACA Board table. Due to the positioning of terms, none of the member-elected Board positions will be up for re-election at the November Council meeting.

The succession plan for the ACA Presidency has had to undergo a change with the departure of Erwin Gamboa, who was Junior Vice President. We thank Huw Dent, whose background was outlined in Corrosion Matters in early September, for stepping forward to take up this role. Erwin's shoes across a wide range of ACA activities will be hard to fill, but I'm sure Huw will ably support the incoming President Matthew Dafter in those responsibilities, at least.

In closing, I should also note the departure from the ACA staff of Jacquie Martin, whose shoes as events manager will also be hard to fill, but we are sure Lucy Krelle, who has been appointed as her replacement and who members will be able to meet at the conference, will do an admirable job.

John Duncan
President

REMAINING EVENTS FOR 2016

Part of the role of the ACA is to organise events that bring together industry experts to present on new technologies, updates to standards, and share knowledge and experiences via case studies on a variety of projects. Here are the events planned for the balance of 2016.

October

Concrete Corrosion Technical Event
Tuesday 25 October | Adelaide

November

Corrosion & Prevention 2016
Sunday 13 – Wednesday 16 November | Auckland

Asset Management Forum
Wednesday 16 November | Auckland

Branch Events

Each of the 8 ACA Branches will conduct regular technical events throughout 2016. To enquire, you may contact your local Branch at the following email addresses:

New South Wales: nsw@corrosion.com.au
New Zealand: nz@corrosion.com.au
Newcastle: ncl@corrosion.com.au
Queensland: qld@corrosion.com.au
South Australia: sa@corrosion.com.au
Tasmania: tas@corrosion.com.au
Victoria: vic@corrosion.com.au
Western Australia: wa@corrosion.com.au

YCG Events

Targeting individuals under 35, new to the corrosion industry and/or interested in the corrosion industry, the ACA Young Corrosion Professionals conduct regular events. For further details email ycg@corrosion.com.au or go to www.corrosion.com.au

THE AUSTRALASIAN CORROSION ASSOCIATION INC
YOUNG CORROSION GROUP

Wesley Fawaz
Executive Officer

Understanding corrosion is essential to successful asset management and so I recently met with the CEO of the Asset Management Council to discuss plans of collaboration for the benefit of both organisations. As a starting point, on page 43 of this issue of C&M you will see a joint Asset Management Forum event has been scheduled during our conference in Auckland. Watch this space as the ACA strives to link corrosion management with asset management and communicate our knowledge to a wider audience for the benefit of industry and our members.

ACA Chairman Dean Wall and myself recently had the opportunity to attend Eurocorr in Montpellier, France (along with approx. a dozen other ACA members including Nick Birbilis of Monash University who was a keynote speaker). Eurocorr is the annual conference of the European Federation of Corrosion (EFC), which is comprised of member societies within Europe and beyond (such as the ACA).

The purpose of our visit was to accept an invitation from the EFC Board to present the ACA course portfolio to the Scientific and Technical Advisory Committee of EFC. Opportunities are now presenting themselves to license ACA courses in Europe and these will be announced as they are confirmed. The ACA also recently conducted its Concrete course in Kuala Lumpur and we aim to build on this in the South East Asia region also.

The ACA Events Manager Jacquie Martin recently resigned after four and a half years with the ACA. Jacquie was a dynamic employee with great capacity to handle many projects and will be sorely missed. But with change comes new employees and new skill sets and I was very pleased to have offered the Events Manager role to Lucy Krelle who is an association professional with a very strong conference and events background managing conferences of up to 3,000 delegates. Lucy has worked for several other associations and is one of only two event managers in Australia that are accredited with Meeting and Events Australia as an In-House Association Meetings Manager. Lucy can be contacted on lkrelle@corrosion.com.au

It's been a year of transition and diversification as well as planning for the next three years with the new strategic plan which focuses on the four key strategic areas of Membership, Training, Advocacy & Communications and Governance adopted by the Board. Demand for NACE CIP continues to slow and the new work experience requirements to undertake the Level 2 examination has significantly impacted on registrations. Uptake hasn't been as high for NACE CP as we had anticipated in the first year and the NACE Pipeline courses were postponed until 2017 due to insufficient registrations. However, industry has taken to the introduction of the new ACA/GAA HDG Inspection course launched this year, with six full courses held in NZ and Australia and the recent update of the ACA Coating Selection & Specification course has also generated a lot of demand.

The annual conference is just around the corner now and it's not too late to register at www.acaconference.com.au. I look forward to seeing you there and please invite as many people as you can too.

Wesley Fawaz
Executive Officer
wesley.fawaz@corrosion.com.au

ACA Training Calendar 2016

ACA/ACRA Corrosion & Protection of Concrete Structures

Member $1115 Non-member $1395

Adelaide October 24 – 25

New Zealand November 10 – 11

NACE CP Thailand

Member $2600AUD Non-member $2850AUD

CP1 - Tester Bangkok November 7–11

CP2 - Technician Bangkok November 14–18

CTC Home Study

Member $2330 Non-member $2730

Start any time

ACA Coating Inspection Refresher

Member $605 Non-member $740

Australia December 5

New Zealand October 29

Corrosion Technology Certificate

(Also offered as Home Study)

Member $2330 Non-member $2730

Sydney November 28 – December 2

NACE Coating Inspection Program CIP 1

Member $3740 Non-member $4275

Auckland October 31 – November 5

Perth November 21 – 26

Sydney December 5 – 10

NACE Cathodic Protection Program CP 1 – CP 4

Member $3335 Non-member $3670

CP1 Melbourne October 17 – 21

CP2 Melbourne October 24 – 28

To express interest an in CP 3 & CP 4, please email aca@corrosion.com.au

IN-HOUSE TRAINING

Did you know that you can have ACA's suite of courses come to you?

The ACA can present any of its courses exclusively for an organisation; we can also tailor any course to your organisation's specific needs. Please contact the ACA's training department on **+61 3 9890 4833 or aca@corrosion.com.au**

All Australian course fees listed are GST inclusive. All NZ and Thailand course fees are exempt from GST.

To calculate the fee pre-GST, divide the fee by 1.1

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Water-Resistant Thanks to a Biofilm

Moisture can destroy mortar over time – for example when cracks form as a result of frost. A team of scientists at the Technical University of Munich (TUM) has found an unusual way to protect mortar from moisture. When the material is being mixed, they add a biofilm – a soft, moist substance produced by bacteria.

Oliver Lieleg usually has little to do with bricks, mortar and concrete. As a professor of biomechanics at the Institute of Medical Engineering (IMETUM) and the Department of Mechanical Engineering, he mainly deals with biopolymer-based hydrogels or, to put it bluntly, slime formed by living organisms.

These include bacterial biofilms, such as dental plaque and the slimy black coating that forms in sewage pipes. "Biofilms are generally considered undesirable and harmful. They are something you want to get rid of," says Oliver Lieleg "I was therefore excited to find a beneficial use for them."

Inspiration from a conversation

During a conversation with a colleague at TUM, Lieleg came up with the idea of using biofilms to alter the properties of construction materials. Professor Christian Große holds the Chair of Non-destructive Testing. Among other things, he investigates self-healing concrete whose cracks close autonomously. One variant of this concrete contains added bacteria. Activated by the ingress of moisture, the bacteria close the cracks with metabolic products containing calcium.

For his own project, Lieleg used mortar instead of concrete. Instead of mending cracks after damage has occurred, he wants to prevent moisture from penetrating into mortar in the first place. Such invading water can cause serious problems, for example by inducing the growth of mold or widening existing microcracks through freeze-thaw-cycles. To prevent such water ingress, he takes advantage of the fact that some bacterial films are highly water-repellent. In the journal Advanced Materials, Lieleg and his colleagues describe how to make a moisture-resistant hybrid mortar.

A soil bacterium produces the bio-supplement

The key ingredient in the new material is biofilm produced by the bacterium Bacillus subtilis "Bacillus subtilis normally lives in soil and is very common microorganism," Oliver Lieleg explains "For our experiments, we used a simple laboratory strain that grows rapidly, forms plenty of biomass and is completely harmless." Lieleg's team bred the bacterial film on standard culture media in the lab. They then added the moist biofilm to the mortar powder.

In the generated hybrid mortar, water was significantly less able to wet the surface compared to untreated mortar. To evaluate this surface property, the scientists measured the contact angle between water droplets and the surface. The steeper this angle, the more spherical the drops are, and the less likely the liquid is soaked into the material. Whereas this angle is only 30 degrees or less on untreated mortar, it is three times as high for drops on the hybrid mortar. Water droplets on polytetrafluoroethylene, better known by the trade name 'Teflon', have a similarly high contact angle.

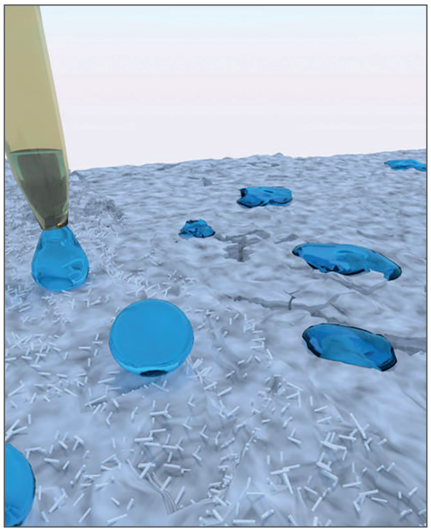
Nanostructures in the mortar

An explanation for the water-repellent properties of the hybrid mortar can be found in electron microscope images: the surface is covered with tiny crystalline spikes. This results in what is known as the lotus effect, which also occurs on the leaves of the lotus plant. The small uniform structures on the surface ensure that only a small part of a water droplet is actually in contact with the leaf surface. The surface tension of the droplet therefore is stronger than the forces that make it adhere to the leaf. Consequently, the droplet easily rolls off the leaf when the leaf is tilted. A cross-section of hybrid mortar shows that crystalline spikes are not only evenly distributed on the mortar surface but can also be found throughout the bulk volume of the mortar. This reduces the capillary forces that are normally responsible for the uptake of water in mortar when the material is immersed into liquid.

Although similar spikes also occur on untreated mortar, they are too long, rare and scattered for the lotus effect to occur. The researchers assume that the added biofilm stimulates uniform crystal growth throughout the volume of the hybrid material.

To find out if the hybrid mortar is resistant enough to actually be used in construction applications, it is currently undergoing mechanical tests in Christian Große's department "If the mortar is in fact suitable, there should be no problem for companies to produce it on a large scale," Oliver Lieleg says. Both the bacterial strain used and the culture media are standard and relatively inexpensive "We've also discovered in our experiments that freeze-dried biofilm can be used equally well. Then, in a powder form, the biological material can be stored, transported and added much more easily." In the future, the scientists want to examine whether the biofilm can also be used to protect concrete against water.

Story courtesy www.tum.de



The surface of the hybrid mortar (left) is covered with tiny crystalline spikes. This results in the so-called lotus effect. (image: Stefan Grumbein / TUM).

Calling for an Awards Committee Representative

Each year the ACA Awards Committee considers papers published in the proceedings of the ACA Annual Conference and Corrosion and Materials for the following Awards.

Marshall Fordham Award

– Best Research Paper

Arthur Kennett Award

– Best Research Paper dealing with non-metallic materials

David Whitby Award

– Best Review Paper

The papers are judged in accordance with a set of guidelines available on the ACA web site.

Due to the recent resignation of Dr. Erwin Gamboa from the Awards Committee, a vacancy exists on that Committee. The other members of the Committee are Les Boulton and Bruce Hinton.

The ACA is seeking a current ACA member to fill this vacant position. The successful applicant will be required to read and assess papers from the two sources indicated above over the course of two months, and together with the other members of the Committee decide on the paper to receive the Awards. This process is carried out in strict confidence.

Applicants should have a broad experience in corrosion science and engineering, and have a background in either industry, academia or industry based research. It is important that applicants have the ability to review papers critically against the selection criteria.

Applications briefly describing the qualifications and experience of candidates should be forwarded to Wesley Fawaz at wesley.fawaz@corrosion.com.au by 16 December 2016.

Microbes Corrode Steel in Ships and Marine Infrastructure

Rust is the bane of steel, whether on cars, on ships and boats, or as part of marine infrastructure. Now, contrary to previous thinking, it turns out that the ocean-dwelling, steel-corroding species, Mariprofundus sp. DIS-1, can thrive under aerobic conditions, rather than being limited to "micro-aerobic" or anaerobic conditions. That means steel in marine environments is more vulnerable to bacterial depredations than previously thought. The research was published on September 16 in *Applied and Environmental Microbiology*, a journal of the American Society for Microbiology.

"We followed up this initial finding by obtaining the genome sequence of strain DIS-1, and found that it possessed a suite of oxygen tolerance genes that are not found in other members of the Mariprofundus genus," explained corresponding author, Adam C. Mumford, PhD, who is currently a Mendenhall Fellow in the Eastern Branch of the National Research Program of the US Geological Survey.

"Going in, the goal of the project was to gain a clearer picture of how iron-oxidizing bacteria colonize steel in the marine environment," said Mumford, who performed the work in David Emerson's laboratory at the Bigelow Laboratory for Ocean Sciences, East Boothbay, Maine. Previously, these bacteria had been studied only in jars, which had failed to fully simulate the dynamic ocean environment, said Mumford. To simulate a more natural ocean environment, Mumford designed a continuously flowing system. "We hoped this would give us a better sense of how the bacteria initially attached to, and colonized bare steel," he said. From there, using an imaging technique he developed, he was able to generate 3-D images of the process.

Earlier research had suggested that the corrosion was linked to sulfate-reducing bacteria, which are strictly anaerobic. That had led to a study which had used high throughput sequencing to show that iron-oxidizing bacteria were the initial colonisers, said Mumford, noting that these were largely replaced over time by other, often more corrosive bacteria. "We wanted to figure out how the initial colonisation by iron oxidizing bacteria proceeded, and that question really drove the research," said Mumford.

The research is critical because microbially influenced corrosion is a leading cause of early failure of marine infrastructure, including bridges, pipelines, and port facilities, and is estimated to cost in the billions of dollars per year. "Understanding the basic microbiology of this process is a crucial part of figuring out how to mitigate it," said Mumford.

Story courtesy www.phys.org

How the Air Force Will Attack its Tiniest Enemy: Plane-Corroding Bacteria

The Air Force is aging. "We have the oldest aircraft fleet we have ever had, 27 years old on average," Air Force Secretary Deborah Lee James pointedly observed at this week's annual Air Force Association Conference. Age is a creating a variety of challenges for USAF airplanes including corrosion.

In the past, the Air Force has worried mostly about the damage from environmental factors such as temperature, humidity, and salt water. But materials specialists at the Air Force Research Laboratory (AFRL) recently have come to realize that organic contaminants—mold, mildew, fungi, bacteria—corrode aircraft surfaces more seriously than they had thought. Corrosion caused by living organisms is generated by moisture, humidity, human contact and by the increasing use of drop-in biofuels, and the microbes they bring with them are, for all intents and purposes, eating airplanes. While the Air Force spends approximately $6 billion annually on corrosion issues, up to $1.2 billion of that could be spent on microbiologically-influenced corrosion.

"Microorganisms can eat away at surface materials, and some of the worst areas affected are tight, hard-to-reach areas that maintainers have difficulty disinfecting," said AFRL Biological Materials and Processing team leader Wendy Goodson.

Goodson's team has looked into adapting the Joint Biological Agent Decontamination System (JBADS), developed for chemical warfare decontamination, for use in disinfecting airplanes for corrosion prevention. JBADS is an environmentally controlled enclosure in which an entire aircraft can be heated to temperatures of up to 82°C. They're essentially cooking an F-16. This approach could temporarily rid the plane of biocontaminants, even internal structures inaccessible to maintenance crews. JBADS is to be implemented by 2017 for chemical warfare applications.

AFRL research also indicated that the military's increasing use of biofuels brings its own corrosion problem. Processed from organic materials like vegetable oils and animal fats, biofuels provide a host in which microbes thrive. Their presence can create fuel fouling, fuel degradation, and material degradation. Testing has shown that microbes immediately begin affecting steel and other structural materials in fuel tanks.

Currently the Air Force power-washes fuel storage tanks. But that can't remove every trace of microbial matter, Goodson says, adding that microorganisms begin re-infecting the next batch of fuel as soon as it's introduced into the tank. The AFRL team is likewise working to adapt JBADS for use with storage tanks, teaming its disinfection properties with cleaning.

In addition to the use of biofuels, the Air Force's drive to go green is introducing more environmentally-friendly aircraft coatings which may bring microbes along for the ride too. Human contact may transmit microbes as well, but AFRL researchers aren't confident enough of its impact to recommend that maintainers use gloves or take other measures when working on aircraft.

We'll be watching to see if the Air Force can beat its tiniest enemy.

Story by Eric Tegler
www.popularmechanics.com

Picture courtesy USAF

U.S. Air Force Enlists Team to Maintain Corrosion Control System

The U.S. Air Force (Washington, DC) has enlisted a team of civil engineers at its Okinawa Island base in Japan to rinse down aircraft in order to prevent corrosion.

Based in Kadena, Japan, members of the Air Force's 18th Civil Engineer Squadron (CES) Water and Fuels System Maintenance (WFSM) team ensure the aircraft rinse system, known as "birdbath," is ready for use by aircraft at the Kadena Air Base.

The birdbath plays a key role in maintaining top performance of the aircraft. Without it, the elements present in the Asia-Pacific region would corrode the jets to a point of disuse, the Air Force says.

"The birdbath is very important because the natural elements can affect the plane once it flies," says Staff Sgt. Edward Adade, a technician with the 18th CES WFSM team. "This could increase the corrosion on the planes, which could cost the Air Force a lot of money. This system is the best method for corrosion control, because we're just using regular water to rinse the planes."

The process works like a water fountain, the Air Force explains. Approaching aircraft trigger a sensor, and the water rises for a certain amount of time.

"The aircraft drive on the pressure plate, [and] once the pressure plate is triggered, it kicks on the pumps," Adade says. "The pumps send water through the ballast tanks, and then it sprays the water to wash the plane off."

Although the system is sensor-driven, WFSM team members often check the station powering the birdbath. Senior Airman Jeffrey Kirkham, a journeyman with the 18th CES WFSM team, says his fellow team members will check certain pumps for functionality and monitor the system for consistency.

The water used to rinse the aircraft is chemical-free and goes through a filtration system before its next use, fulfilling a dual purpose of saving money and helping the environment.

"This has been a really unique experience," Kirkham says. "This is one of the largest WFSM shops in the Air Force. I've seen a lot during my time here. I've learned to adapt to a situation and overcome it because of the unique situation we have here in Okinawa."

Story courtesy www.materialsperformance.com

An F-15 Eagle goes through a birdbath at the Kadena Air Base in Japan. The birdbath is a vital component of maintaining the longevity of Kadena's fighter aircraft. The birdbath prevents corrosion from building up on the aircraft. Photo courtesy of Airman 1st Class Lynette M. Rolen, U.S. Air Force

Farewell to Jacquie

Farewell and thanks to Jacquie Martin for her super human efforts at the ACA for managing and developing the Conference, Technical Events and the Foundation programs.

All the very best to Jacquie who is now the Executive Officer for the Vet Nurses (Council of Australia) and Association of Biosecurity for Australia and New Zealand (ABSANZ).

Hello to Lucy Krelle – A new face has joined the ACA Team

Lucy has recently joined the ACA as the Event Manager and her responsibilities are to manage the Annual Conference along with the ACA Technical Events Calendar. Lucy is accredited with the 'In House Meetings Manager' with *Meetings and Events Australia* and has had over 15 years' experience in the events industry, the majority of time spent in the Not for Profit Association sector. In addition, she has worked for two professional conference management companies organizing large scale events. She is very much looking forward to making a significant contribution to the ACA in the years ahead and meeting and working with the Association's membership.

Inaugural ACA – NACE International Certification CP1 & CP2 Courses

Corrosion control enthusiasts from several states attended the inaugural ACA - NACE Certification courses for Cathodic Protection in Brisbane, Australia.

The scheduled back to back certifications for CP 1 – Tester took place from 18 – 23 July 2016 and CP 2 – Technician from 25 – 30 July 2016. Practical and Written exams took place over five hours on both Saturdays.

The CP Instructors Calvin Pynn from Dubai and Bob Phang, now a Brisbane resident, conducted the courses with assistance from trainees Allan Sterling, Ivo Kalcic and Wayne Burns.

Students praised the Colmslie Hotel in Morningside for providing a private board room, more like a training hall with daily coffee breaks and a dine-in lunch.

Calvin, who has taught these courses for 12 years, stated that it "has been a great pleasure to instruct the inaugural NACE CP1 & CP2 classes in Australia. The ACA did a superb job of organizing the venue & equipment and the students were keen, motivated and a joy to teach!! These will undoubtedly be the first of many NACE CP certification courses in Australia."

The next CP 1 and CP 2 courses scheduled to run are in Melbourne from 17 – 28 October 2016.

The ensuing CP 2 – Technician Course ran smoothly at the same venue and several members completed both certification courses back to back successfully.

NEXT Destination Melbourne: The scheduling of both CP1 & CP 2 courses will be an effective way to provide the NACE certifications to a wide spectrum of people in Victoria, Bass Strait being the origin for Oil & Gas producers with trunk mains, distribution pipelines and associated assets.

Bob, a past NACE EAP Director stated that "from 1 September, 2016 the CP exams are **CBT - computer based testing**, newly designed to raise the importance of quality assurance. This change will increase the integrity of the NACE International Institute (NII) Certifications, modernise the program and align us more closely with ISO 17024.

This will augur well as the students will have more time to study the material prior to taking on the written exam. Practical exams will still be conducted at the training venue on the same week."

Bob Phang, ACA Member for 32 years

Practical Exam.

Theory Written Exam.

Qualified CP Staff

Corrosion Control Engineering (CCE) leads the way in Cathodic Protection qualified staff with three NACE CP-4 (CP Specialists) in Australia. Jim Galanos (NSW) and John Grapiglia (WA) join their colleague Iginasio Muvimi (VIC) in this elite club of corrosion engineers, of which there are only a handful in Australia.

The CP-4 course is the highest Level offered by NACE and entitles successful participants to be classed as CP Specialists. **If you would like more information on any of the NACE CP Courses (1-4) please contact Skye Russell at the ACA on srussell@corrosion.com.au**

Vale: Peter Clark 25 August 1927 - 8 July 2016

It is with some considerable sadness that we mark the passing of a true gentleman - Peter Clark. Peter was well known to the corrosion industry not only in Australia but overseas as well. Peter was born on the 25 August 1927 in West Hartlepool, County Durham, in England and died on the 8 July 2016 at the age of 88, in Wyong Hospital. During his time in Australia, Peter was a strong supporter of the ACA.

Peter's approach to life was much influenced by his early years during the Great Depression and the Second World War. He was thirteen in 1940, the time of the Battle of Britain, and eighteen in 1945 when the war ended in Europe and the Pacific.

In 1932 Peter started at Avenue Road Infants School. He later went to Brinkburn Grammar School until 1945. In August 1939, just before the declaration of war, his school was evacuated to Scarborough. He was there until, Christmas 1939. This was the period known as the "phoney war" when there was little fighting and he returned home, as Scarborough seemed no safer than Hartlepool. During the war Peter spent the summers of 1943 and 1944 working on farms, picking potatoes in 1943 and harvesting oats and barley in 1944, which he says was much more fun. He also spent these two Christmases working as a postman.

During the war there was a great need for scientists and engineers and so he was excused National Service because of his high level of schooling and intention to study science at university.

From 1945–1948 he read Metallurgy at the Royal School of Mines, Imperial College London funded by a scholarship.

After graduating in 1948 with a B.Sc (Eng), honours, and ARSM, he took a job with Thomas Bolton in Widnes working in copper smelting. Post-war England was a miserable place with high taxes and rationing so he applied for a job with the Anglo Iranian Oil Company, now BP, and got it, and went to work in the oil refinery in Abadan in Iran as a corrosion engineer. The trip was his first ever flight in an aircraft. When Iran nationalised the oil companies in 1951 Peter was one of the many foreign workers forced to leave. After working on the Isle of Grain refinery in Kent for a while he returned to the Middle East to Kuwait and later Aden.

In 1952 Peter's father became very ill. Peter returned at short notice just in time to attend his funeral. It was on his return trip to Kuwait that he met his wife to be, Connie Sanday, who was heading to Kuwait to work as a nurse for the oil company. They fell in love and married in 1953.

Connie became pregnant with her first son in 1957 and they decided to return to England. David was born in Nottingham in 1958, Jonathan in 1960 and Andrew in 1963 both in Hertfordshire where they had settled.

Returning to England, Peter was engaged on various consulting and turnkey projects in the United Kingdom, 9 European and 10 Middle Eastern countries. Eventually Peter took up work with a company called Mapel, now part of AMEC. In 1966 he was offered work in Australia and moved to Sydney with his family where he worked for Metlab X-ray.

In 1972 he was appointed Executive Director of the Copper and Brass Information Centre in Sydney. Later he worked for Robertson Research and then the Physics Department of the University of New South Wales.

After marrying his second wife, Pamela Kenneth, in 1983 he moved to Melbourne where he became the corrosion consultant to the Department of Minerals & Energy for the Victorian Government. The work involved review of CP reports and other corrosion related matters for licensed Oil & Gas Pipelines in Victoria. He retired from there in 1992. Sadly Pam became ill with cancer and died shortly after.

Left alone he went back to working. In the early 1990s Peter was appointed as Engineering Manager at Solomon Corrosion Control Services in Melbourne. In this position he overviewed projects performed worldwide by the offices in Kuala Lumpur, Guam, New Plymouth, Sydney and Melbourne.

In 2002 at the age of 75 he semi-retired again and moved to Blue Haven on the NSW Central Coast. He continued his corrosion consulting work, most recently advising on a fuel pipeline for Hong Kong International Airport.

Peter had a great, lifelong interest in trains and railway modelling, particularly the London and North Eastern Railway. This was the company that served the Hartlepool area before nationalisation and, of course, another major influence from his childhood. He has a large collection of books and magazines about railways and was interested in railway modelling. Throughout his life he had the ambition to create a large model railway layout in his home. To this end he collected a large amount of model locomotives, rolling stock and track but somehow it never came to fruition. In his garage today there is the start of a model railway base but without any track. This was never completed. Regardless of his love of railway modelling, his love of work was even greater.

Others were most impressed by his staggering intellect, his work ethic and vast knowledge of his professional field of corrosion, of history, of trains, of metals and chemistry and his continuation of his corrosion consulting work up until the last year or so of his life.

Peter was passionate about his work and had a strong understanding of the physics and chemistry of corrosion. His background was metallurgy. He also had an excellent understanding of electrical induction and safety requirements. Peter's dry sense of humour was typical of his English heritage. His use of the English language to its fullest often left his colleagues reaching for their dictionaries in order to understand what had been said.

Peter was a member of the ACA since 1985, initially in Melbourne and since his moving to the Central Coast was strong supporter of the Newcastle Branch. Peter was a regular attendee at the Newcastle ACA meetings from 2002 onwards until ill-health made travel too difficult. A few years ago Peter gave a Branch presentation regaling us with stories of his experiences, particularly in the Middle East. On many occasions he visited Newcastle University to discuss various aspects of corrosion.

Peter Clark was one of the GOMOCs (Grand Old Men of Corrosion) of our industry and we are proud to have known him and worked with him. With his passing away he will be sadly be missed.

Collated by Robert Jeffrey with many thanks for input by his son David and good friend John Tanti.

Optimising Concrete Assets and Extending their Service Life

PROUDLY PRESENTED BY:

AUSTRALASIAN CORROSION ASSOCIATION INC.

Adelaide
26 October 2016

Overview

The Concrete Structures & Buildings Technical Group of the ACA has produced a technical program that will investigate and discuss the repair and maintenance of concrete assets across a range of industry sectors. This event will continue to build on the success from previous concrete themed events.

It will focus on real life case studies, exploring both successes and failures. The presenters will share their experiences and the lessons they have learnt with a focus on extending service life.

Venue

Crowne Plaza
16 Hindmarsh Square
Adelaide, South Australia

Contact

For further information on this event please contact
Bianca Reardon on +61 (0)3 9890 4833 or Reardon@corrosion.com.au

Cost

ACA Members - $250 (inc GST)
Non Members - $295 (inc GST)

Program

Time	Session	Speaker
8.30 – 9.00	**Registration**	
9.00 – 9.10	**Welcome and Seminar Opening**	
9.10 – 9.50	Inspection; a Burden or an Investment?	Paul Vince, SA Water
9.50 – 10.30	Reflections on the Design, Construction and Operation of Concrete Assets in Desalination Plants	Frederic Blin, AECOM
10.30 – 11.00	**Morning Tea**	
11.00 – 11.40	The use of Cementitious Coatings to Repair Low Nominal Cover on Reinforced Concrete Structures	David Johnstone, International Paint
11.40 – 12.20	Extending the Service Life of a Sydney Icon – A Case Study of the D&C MLC Tower Façade Maintenance Project	Tom Wenzel, Freyssinet
12.20 – 13.00	Concrete failure of Bridge and Marine Structures.	Clive Blanchard & Hannah Watchman, DPTI
13.00 – 13.50	**Lunch**	
13.50 – 14.30	Service Life Modelling, Rehabilitation and Maintenance to Optimise and Extend Service Life	Marcin Wieloch, GHD
14.30 – 15.10	Evolution of Galvanic Anodes in the Mitigation of the Incipient Anode Effect	Colin Peterson, BASF
15.10 – 15.40	**Afternoon Tea**	
15.40 – 16.20	Case Study: Concrete Durability at the Adelaide Desalination Plant	David Gardiner, SMEC
16.20 – 16.55	**Open Forum**	
16.55 – 17.00	**Seminar Close**	
17.00	**Networking Drinks**	

For more information and to register visit www.corrosion.com.au

PLATINUM MEMBERS

- 3C Corrosion Control Company
- AECOM
- ALS Industrial
- Anode Engineering
- apa
- ATTAR Advanced Technology Testing and Research
- Blygold Oceania
- Bureau Veritas
- carboline Coatings · Linings · Fireproofing
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- JOTUN
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- Santos
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- select solutions An AusNet Services Business
- Sika Building Trust
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- XYPEX Sustainability in Concrete Structures
- ZINGA

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- GHD Clients | People | Performance
- GMA Garnet Group when your abrasive matters!
- GPC Goldfields Protective Coatings
- HG Hunter Galvanizing
- HydroChem Water Specialists
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- ics inspection & consultancy services ltd
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- KAEFER NOVACOAT
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- Urrumbeena Industrial Spray Painting Pty Ltd Specialists in Industrial Spray Painting
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- stanwell create. generate. innovate.
- Steuler KCH
- TBS Corporation
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- Dept of Transport and Main Roads
- Dept of Infrastructure, Energy & Resources
- Dept of Transport
- DH Corrosion-DPC Coatings
- Diagnostech Pty Ltd
- DMF Sandblasting & Painting
- Doito Pty Ltd
- Doogood Specialised Coatings P/L
- Downer Edi Engineering Power Pty Ltd
- DST Group

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VT Industrial Coatings
WAG Pipeline Proprietary Ltd
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ACA Welcomes New Members

Corporate Platinum

Imatech
www.imatech.com.au
Imatech is one of the most innovative solutions providers in industrial wear protection solutions with a focus on the mining and minerals processing industry. With over 30 years of combined practical experience with the best available products in the market, Imatech delivers competitive and comprehensive tailored solutions with engineered reinforced polymer composites, rubber-ceramic wear liners, rubber repair products, engineered abrasion and resistant pipeline systems, maintenance products and complete pump solutions.

Corporate Gold

Independent Monitoring Consultants
www.imclive.com
IMC is a privately owned Australian company providing quality services since 1992, and was the first to introduce full independent sampling and testing to help clients manage the control of legionella, system corrosion, OHS and duty of care obligations.

Oceaneering
www. oceaneering.com
Oceaneering is a global oilfield provider of engineered services and products primarily to the offshore oil and gas industry, with a focus on deep-water applications. Through the use of its applied technology expertise, Oceaneering also serves the defense, entertainment, and aerospace industries. Oceaneering's business offerings include remotely operated vehicles, built-to-order specialty subsea hardware, deep-water intervention and manned diving services, non-destructive testing and inspection, and engineering and project management.

Corporate Bronze

Central Highlands Water
chw.net.au/about-us/our-organisation
Central Highlands Water is a regional water corporation providing high quality drinking water, sewerage, trade waste and recycled water services to customers in Ballarat and surrounding towns. Formerly known as the Central Highlands Region Water Authority, it is one of 19 state-owned water businesses operating under the guidance of the Victorian Water Act. Providing fully integrated catchment-to-tap-to-catchment water services, we collect, store, filter, disinfect and deliver water, and collect and treat wastewater.

Downer Edi Engineering Power Pty Ltd
www.downergroup.com
Downer is a leading provider of services to customers in markets including: Transport Services; Technology and Communications Services; Utilities Services; Engineering, Construction and Maintenance (EC&M); Mining; and Rail.

At Downer, they support their customers through the life of their assets - from initial feasibility and design through to production and operations and eventual decommissioning.

Integral Engineering Pty Ltd
www.integraleng.com.au
Integral Engineering Pty Ltd (Integral) is a new Mackay based engineering firm that provides high quality and cost effective engineering solutions to clients in the Central Queensland region.

Napier Sandblasting Co Limited
www.nsb.net.nz
Napier Sandblasting is a family owned business stretching back three generations. They are now one of New Zealand's largest corrosion control companies, with site crews spread throughout the country, particularly the North Island.

Simply put, they do corrosion control, on structures large and small. Their specifiers, applicators and corrosion technicians know how to put the right coating system in place – to last without costing a fortune.

Pipe Lining & Coating Pty Ltd
www.pipelining.com.au
Pipe Lining and Coating Pty. Ltd. (PLC) is a leading Australian Specialist Manufacturer and Supplier of Mild Steel Cement Lined Pipes and Fittings. Our 25 years supply history of these products allows PLC to provide a competitive and comprehensive solution which is supported with Quality Accreditation (ISO 9001:2008) and Australian Standards Mark Certification (AS1579-2001).

Quick Strip Dustless Blasting Services
Mobile on site, dustless blasting, non-sparking (ideal for gas and petroleum sites). 100% Eco Friendly. Inhibits rust for 72 hours and is instantly ready for painting. Will not kill grass or plant life like soda blasting will. Aviation, Automotive, Domestic, Industrial, Mining, Marine. Removes anti-foul from boats and marine structures, heavy plant equipment (mine, gas, petroleum sites) Removes rust and corrosion from all types of materials. Removes road markings and graffiti (timber, brickwork, concrete). Exposes Concrete aggregate. Swimming pool restoration (painted, tiles. fibreglass). Restores tiles and pavers (anti-slip). Our Qualified spray painters can replace all coatings on your project to exacting engineered specifications that are required for today's high quality international standards.

Renroc Group Australia
www.renrocgroup.com
Renroc Group (Pumps & Engineering) was established in 1991. It was formed to develop a small and growing segment in the Australian Pump industry for hermetically sealed pumps. The company produces a unique and important product for a growing market. The business (RGA) specialises in the design and construction of Fluid Handling Systems for the world's leading EPCM Contractors in the Oil & Gas, Petrochemical, minerals extraction, refining companies and utility suppliers.

Trelleborg Marine Systems Pty Ltd
www.trelleborg.com/en/marine-systems
From port owners and operators to consulting engineers, Trelleborg works with customers to determine best fit solutions for specific applications, and supply a fully integrated solution. End-to-end service and a comprehensive product portfolio meet and exceed customer needs, enhancing safety and improving efficiency in all marine environments, from conception to completion and beyond.

ACA Auckland Division

July Meeting Report

The ACA Auckland Division meeting held on July 27th at The Landing hotel was addressed by Ash Arya, Managing Director, CSP Coating Systems, on the subject of "*How to avoid falling street lighting poles*". CSP Coatings specialise in hot-dip glavanizing steel and supplying specialised paint coatings on glavanized steel, i.e. duplex coatings. CSP glavanize steel poles that are widely used throughout the country for street lighting. There have been a few cases arise over the years where the lighting poles have corroded at ground level resulting in the collapse of the street lighting columns. This problem poses a safety issue to the public and has to be avoided at all costs. In his address Ash first described the pole corrosion mechanism and then he explained how the problem is being overcome by the industry.

Corrosion on ground-planted lighting poles is usually initiated by a prevailing micro-environment (e.g. aggressive soil and poor drainage) combined with a macro-environment (e.g. geothermal or marine) that contribute to the pole corrosion mechanism. In 1994 the falling pole problem was addressed by the NZ Transport Agency and the Standard TNZ M/19 was developed involving application of a 150 micron (DFT) epoxy 'strip' on the glavanized poles and the pole stub bases at ground level. However, the solution was not always successful due to delamination of the epoxy coating.

In 2012 an upgraded Standard NZTA M/26 was introduced that required either an epoxy mastic strip (350 microns DFT) or a 100% volume solids coating of polyurea or polyurethane (800 microns DFT). Ash explained that the polyurea protective coating system was used globally and it has also proven to be very successful in NZ to avoid street lighting pole corrosion. The ongoing development and improvement of the polyurea Tuff Coat system for application on ground-planted glavanized steel street lighting poles at CSP Coating Systems was outlined.

An extensive Q&A session followed the presentation and Ash adeptly fielded many questions relating to this specialised field of corrosion control. The meeting concluded with Chairman Raed El Sarraf thanking Ash for his interesting address.

Ash Arya discusses his presentation with attendees after the meeting.

Ash Arya of CSP Coating Systems presenting at the ACA Auckland July meeting

Early Bird Prize Winner!

Congratulations to Murray Cross of Transpower, Palmerston North, who won the **ACA Corrosion & Prevention-2016 Conference** *Early Bird Registration Competition*.

Murray has won four nights' accommodation at Sky City during C&P2016 in Auckland and a SkyWalk experience for two on the Sky Tower. The prize is valued at over $1400.

Enjoy the ACA Conference in Auckland, Murray.

CORROSION & PREVENTION 2016

PROUDLY PRESENTED BY:

MAJOR SPONSOR:

13-16 November | SKYCITY Convention Centre | Auckland, NZ

ACA Qld Visit to Cathodic Anodes

Queensland ACA members were recently treated to a rare glimpse inside a Sacrificial Anode Cathodic Protection production facility. Cathodic Anodes Australasia (CAA) kindly offered members an exclusive opportunity to tour their foundry and laboratory located on the Sunshine Coast. The ACA provided bus transportation to and from Brisbane CBD, with morning tea and lunch generously supplied by CAA.

CAA has been operating since 1984 and have since established themselves as a leading galvanic anode manufacturer in Australia. The tour included a walk around their purpose built casting plant and testing laboratories. ACA members were able to see zinc and aluminium anodes in production as well as laboratories containing Optical Emission Spectrometer, metal consumption rate and closed circuit potential testing equipment.

Farewell to 'Erk' Gamboa

The SA Branch Committee wishes to thank and acknowledge Dr. Erwin 'Erk' Gamboa for his dedication and contributions to the ACA since joining in 2005.

Erk has recently accepted a position In Calgary with TransCanada Pipelines, where he will be able to apply his extensive academic experience with Stress Corrosion Cracking.

Erk has held a swag of important positions at both Branch and National level including;

- Member of the Australasian Corrosion Association (ACA) continuously since 2005
- ACA State Committee Member (2005-2016)
- ACA Young Corrosion Group National Chairman (2009-2014). Developed framework for modern YCG, helping support young corrosion professionals
- Councillor (South Australia) to the ACA National Council (2009-2010)
- ACA National Conference organising committee (2009-2010, 2015)
- ACA Awards Committee member (2010-2016)
- ACA Secretary to the State Committee (2012)
- ACA National Conference technical review panel (2013-2016)
- South Australia ACA Committee Vice President (2015)
- ACA National Conference Technical Chair (2015)
- ACA 'Corrosion & Materials' publication reviewer (2016)
- ACA National Junior VP (2016)

Congratulations on your next career step, and a huge thanks for all of the energy and effort you have put into ACA, and particularly in getting the next generation involved. You will be a hard act to follow.

John Duncan
ACA President 2016

His experience, loyalty, leadership and 5 toed shoes will be missed by many. We wish Erk and his family all the best for the future and hope to see him back on Aussie soil at some stage

Alex Shepherd
President SA Branch

QLD Branch Event

Get us to the Greek!

The Brisbane Greek Club to be precise! On Wednesday 24 August, the Queensland Branch held a series of case study presentations at the centrally located Greek Club in Brisbane. A good crowd turned up to listen to some knowledgeable speakers, network and enjoy some plentiful eats and drinks offered at the venue.

The speakers introduced the audience to a number of locally relevant projects and their specific challenges. The Queensland Branch president, Nick Doblo introduced Mike Rutherford from Freyssinet who proceeded to explain the remediation and protection project he undertook on a sewerage rising main (SRM). Mike began the talk explaining what a SRM was and how it worked. They are generally difficult to work on due to the nature of their function with their location providing a site access challenge and the risk of gas build-up. The section worked on was 800 metres long and the SRM is supported by concrete footings; every fifth one is an alignment block. The real challenge was that this SRM was in a sensitive mangrove area, providing tidal access and environmental challenges. The remediation included footing modifications, reconstruction, interface sealing, cathodic protection and application of a protective coating. Hydro demolition was used to cut out 25mm of concrete between the headstock and pipe. Structural epoxy was injected for crack repair. The end result should have the SRM performing its innocuous service for the next 50 years. Mike was also quick to add that the location was a great source of blue crabs. The secret location is safe Mike!

Mike was followed by Kevin Woodland and Victor Manriques from SMEC who detailed the challenges associated with inspection and remediation of the Cowper Street Siphon in Brisbane. The siphon transfers sewerage waste from 55,000 people from the suburbs of Bulimba to Hamilton. As these are either side of the Brisbane river, the integrity of the siphon and tunnel are paramount. The most immediate challenge was access, as the siphon is located in a purpose built tunnel commissioned in 1955. The aims of the project SMEC undertook was to; assess the condition of the siphon, establish its remaining life and undertake urgent repairs. Many inspection methods were considered including; broadband electromagnetic scanning, remote field eddy currents, long range ultrasonic thickness test and standard ultrasonic thickness testing. Due to cost considerations the latter assessment method was preferred. Despite 80% of the coating adhesion tests failing, general pitting was acceptable. Four options were put to the client with various short and long term cost implications. These were to a) do nothing b) localised patch repairs c) major remedial works and d) continuous inspection for repair. The presentation highlighted the access challenges faced with inspection and repair crews when faced with confined space restrictions.

As a late replacement as third speaker, Nick Doblo from APA Group then finished the evening with a professional description of the increasing challenges faced when managing older infrastructure. The challenges faced were not only due to the age of the materials, but also by surrounding infrastructure as it is built up around existing assets. The case presented was a gas pipeline increasingly influenced by CSG wellheads in its immediate surrounds and a new water pipeline servicing new residential developments all influencing the cathodic protection systems protecting his employer's assets.

All the speakers answered some vigorous questions relating to their talks and the attendees all enjoyed the eats and drinks in the convivial environment the Greek Club offered. Some of the newer members vowed to be back at the next ACA event!






Taranaki Branch

The ACA Taranaki Branch hosted a 1-day technical event on 4 August, 'Corrosion in the Oil Gas Industries 2016'. Following successful events in previous years, this was another well-attended event in New Plymouth with over 50 registrants from around New Zealand and Australia. With thanks to two main sponsors, International Paint and Olympus, and 15 trade table exhibitors, the day included seven technical presentations, a speaker's forum and networking sessions.

The day started with an interesting talk on power generation equipment failures from Stephen Rowbotham of Quest Integrity, presenting examples of interesting metallurgical failures and emphasising the importance of root cause analysis. Matthew Brown of International Paint spoke about selecting suitable coatings based on specifications and known product performance, and emphasised the importance of understanding cyclic and non-cyclic accelerated test methods.

It was noted that we have some very aggressive corrosion categories in New Zealand to consider when protecting onshore and offshore assets. A mineralogical guide to corrosion was presented by Jake Jarvinen of Olympus. This described the various compounds that exist in corrosion product/scale; how they can be analysed with modern instruments to understand the scaling formation and how corrosion problems can be resolved. Mick Ellem of Shell Todd Oil Services presented some interesting metallurgical failure case studies related to steel fabrication and heat treatment. Grahame Strong of Corrosion Control Engineering talked on the usefulness and limitations of using external corrosion direct assessment (ECDA) on buried pipelines, and how we should take all opportunities to assess integrity, remembering corrosion is not the only failure mode. Anita Zunker of Pressure Equipment Integrity discussed fundamental corrosion damage mechanisms and the Risk Based Inspection (RBI) approach to asset integrity. A number of case studies were presented covering various corrosion types and industries. Garth Moran of Carboline described numerous internal and external coating systems for pipeline corrosion protection, buried and above ground. On some systems protecting for corrosion under insulation, a common failure was noted at transition points where the coating was not suitable for UV exposure.

The high calibre of speakers and interesting selection of presentations prompted a number of questions. The speakers forum session, to end the day, was wound up after nearly an hour of discussion between all presenters and attendees.

We look forward to seeing everyone at the next Taranaki event.

Ry Collier

VIC Branch Annual Case Studies Evening

It's September, so it's time to hear interesting short stories about corrosion and its defeat. Sponsored by long time supporter Denso, The Royal Society meeting held on 14 September heard about stray currents, galvanizing durability, unexpected coating failures and the welcome resistance of a 3MW hydroelectric plant to immersion in flood waters.

Peter Mart from DST Group described some issues with a seawater cooling system which suffered from significant biofouling and pitting and crevice corrosion of the 316L stainless steel pipework. Despite implementation of some corrective measures, extremely rapid corrosion of a 316L flange was still an ongoing problem. After a concentrated team investigation, the problem was traced to stray currents although the use of 316L in seawater was a long standing offshore design problem. Some engineering work involving change to copper based piping materials was successful in correcting the problem.

We then moved to coatings inside waste water tanks on boats. Ted Riding from Jotun described a very difficult internal paint job (and the ire of painters faced with a long extension inspection mirror) which meant that a massively over thick coating was applied – and promptly cracked. Unfortunately, the tank was designed to be 50% full and was the recipient of treated sewerage when the boat was moored. The H_2S in the atmosphere dissolved in the water films in the ullage space providing an aggressive low pH which stripped the coating and caused pitting within a couple of years. Better application of an appropriate coating together with ventilation of the ullage space solved the problem.

The last two talks were more immediately positive. Ann Sheehan from the Galvanizers Association of Australia described the 13 year inspection of a waterfront car park that was built to OneSteel's design recommendations. The corrosion protection included a mixture of galvanized, organic coated and duplex systems with some thoughtful touches to protect coatings such as bolts with locking tabs and washers larger in diameter than the bolt heads. Overall the protection system was in good condition in this nominally C4 environment and required relatively minor touchup. However, the pristine condition of the galvanized cast-in-place formwork for the concrete decking and some heavily corroded purlins in the top deck's shelter illustrated how micro-environments can dominate the broad corrosion classification.

The final talk by Sarah Furman from AECOM was a walk through the durability of a 60 year old hydro-electric turbine and its draft tubes associated with a flood control dam on a semi-tropical river. The system had had a hard life with changes of operating ownership followed by a period of neglect and then inundation by a major flood. Drawings and maintenance records were scant so the inspection was both to assess corrosion and measure dimensions. Access was, to put it mildly, difficult and involved stripping out the internals and using nimble inspectors. Wall losses were relatively small although they were greater in the poorly drained bottom of the water chambers. The exterior was decorated with patch coating repairs in contrasting colors and interior metal loss, for example of turbine blades, had been refurbished by using metal putty! Overall, the electrics were obviously scrap but, apart from some discrete components which required replacement, the major components are still reusable after repairs to the protective coatings.




ACA Auckland Meeting Report 1

At the ACA Auckland Young Corrosion Group (YCG) meeting held at the Billfish Café, Westhaven Marina, on August 18 the speaker was Graham Lee, Business Development Manager for A.S.Harrison & Co Pty Ltd. Graham's presentation was entitled '*If it wasn't so damaging just consider the sheer beauty of corrosion*'.

Graham commented that the world of *corrosion prevention* is interesting, but people focus a lot on prevention of corrosion without seeing corrosion for what it sometimes is – *art* . His presentation recognised how damaging corrosion can be, but also how 'beautiful' corrosion can be. Using images that he had collected over twenty years in industry, Graham took the audience on a journey into the world of corrosion art.

The presentation illustrated how we all look at things differently. Some just see corrosion damage while others see corrosion art. Both art and damage can be present at the same time and Graham's presentation opened the attendees' eyes to some quite different aspects of corrosion.

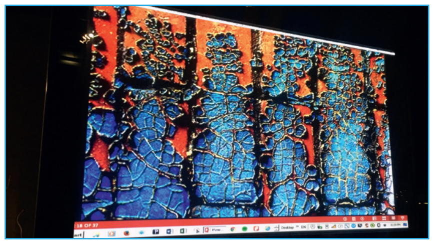
Chairman Raed El Sarraf then thanked Graham for his well-illustrated presentation and the YCG attendees continued to enjoy an excellent social occasion at the Billfish Café.

You can view more of Graham's great corrosion images at www.pinterest.com/gjlee2176

Chairman Raed El Sarraf introduces the YCG speaker Graham Lee

Corrosion Art 1.

Graham Lee chats with some YCG attendees after his presentation



Corrosion Art 2.

ACA Auckland Meeting Report 2

The ACA Auckland meeting held on 28 September at The Landing hotel was addressed by Wayne Thomson, Managing Director, Anode Engineering Ltd and Lordco NZ, on the subject of '*Corrosion Monitoring in a Marine Environment*'. Wayne is based in Brisbane, but he is well known to the ACANZ membership from his previous working life in NZ.

Wayne explained how aggressive marine environments provide many challenges to asset managers responsible for working ships, boats, wharves, piling and sub-sea pipelines. The life and maintenance of logistically important marine assets can be managed efficiently by employing special monitoring equipment, including corrosion monitoring techniques (CM). He then described why it is important to monitor the corrosion on marine assets and infrastructure during their life cycle. Using CM is a key part of maintenance planning for all marine assets to ensure long trouble-free service.

Wayne then outlined the various CM techniques that are available nowadays for corrosion monitoring in various environments including the marine atmosphere and in sea water. In particular, he described the installation and use of the *corrosion coupon* and *electrical resistance* (ER) methodologies. The corrosion coupon technique is a well-known technique that gives valuable information on corrosion types occurring and metal corrosion rates. Samples of different corrosion coupons available were passed around for inspection. Wayne then moved on to outline the ER technique involving special ER probes and data loggers to give real-time corrosion rate information for metals exposed in marine environments. The ER method is frequently used in conjunction with *corrosion prevention systems* employed on the hulls of working ships in sea water for monitoring the efficiency of ICCP systems installed on the ship hulls.

After an extensive Q&A session in which Wayne fielded some interesting questions from the audience, Chairman Raed El Sarraf thanked him for his very informative presentation

Wayne Thomson discusses the use of ER probes and data loggers with members of the audience.

Raed El Sarraf (Chair- left), Wayne Thomson & Jeffrey Robinson from Lordco .

Newcastle YCG Trivia Night

The Newcastle Branch of Young Corrosion Group (YCG) held their inaugural event at a joint event with the Newcastle branch of Young Engineers Australia (YEA) to co-host a trivia and professional networking night on Friday 9 September at the Newcastle Cruising Yacht club. The event received a turnout of over 50 young engineering professionals from a variety of industries. The team from the Science and Engineering Challenge set a task to each table to create a catapult from chopsticks, rubber bands, and a spoon which resulted in a lot of enjoyment and engagement across the night. The Newcastle YCG would like to thank YEA for co-hosting its inaugural young corrosion event and the team from the Science and Engineering Challenge for its assistance on the night. Congratulations to Matt Eaton for winning the lucky door prize, which is a free ticket to our next branch technical talk.

VIC Branch Event - 18th Technologists Picnic

The Annual Combined Societies Event: 18th Technologists' Picnic – was held at The Charlie Napier Hotel, Sovereign Hill Outdoor Museum, on Friday 2 September. The title of the event 'Bastion Cycles: The use of advanced manufacturing techniques for bicycle frames' was enjoyed by 30 people from the various associations. These annual dinner-meetings have customarily been arranged by Materials Australia and supported by members of Engineers Australia, Australasian Corrosion Association, Australasian Institute of Mining and Metallurgy and the Australian Foundry Institute. This year WTIA has also joined.

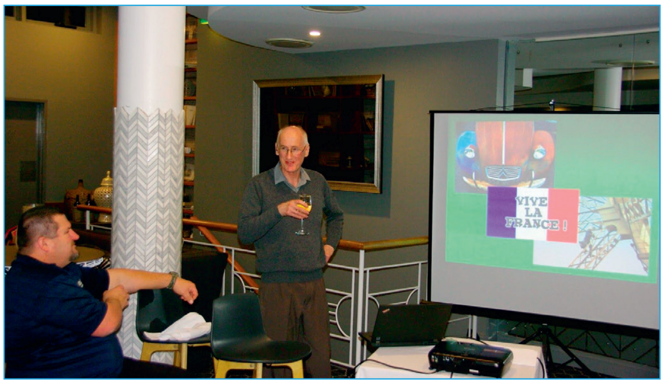
Newcastle Branch Event

In July, Newcastle Branch was honoured to host Rob Francis as the speaker for their technical event. Rob Francis is a corrosion and coatings specialist with over 40 years' experience in corrosion and its mitigation, especially in the area of protective coatings for steelwork for atmospheric environments. He is an Australasian Corrosion Association Past President, Corrosion Technologist and Coating Inspector, a NACE Certified Coating Inspector and Trainer and is Chairman of Australian Standards committee MT14/2, which has developed AS/NZS 2312 on the selection and application of protective coatings. He edited the publication 'Sixty Years of Inorganic Zinc Coatings', in 1998, which was revised and expanded in 2013. Rob was made a JPCL Top Thinker in 2012 and awarded the ACA Victor Nightingall Award in 2014.

The topic of Rob's presentation was his involvement with a painting contract for a large coal stacker/reclaimer that was undertaken in South Korea, which provided a valuable case study showing issues and problems which can arise with overseas painting contracts. In this example, the asset owner required application of a quality protective system so thorough on-site inspection of the work was needed. Problems encountered arose both from the quality of fabrication and the quality of the coating application achieved on site, as well as cultural differences. Rob highlighted how with all coating work, blasters, painters, inspectors and coating suppliers need to work together and adapt procedures as required.

The day of the presentation was coincidentally Bastille Day, so a toast was raised to France!

There were approximately 30 attendees and all very much enjoyed the insights that Rob had to offer regarding the cultural differences when working overseas. Rob's aversion to kimchi was noted! Rob also provided excellent advice regarding the technical aspects required in order to achieve a high quality coating that is compliant with the specifications.



Hosted by:

Australasian Corrosion Association Inc. · APGA

Sponsors:

CCE Corrosion Control Engineering · Canusa-CPS · UCC

Cocktail Function Sponsor:

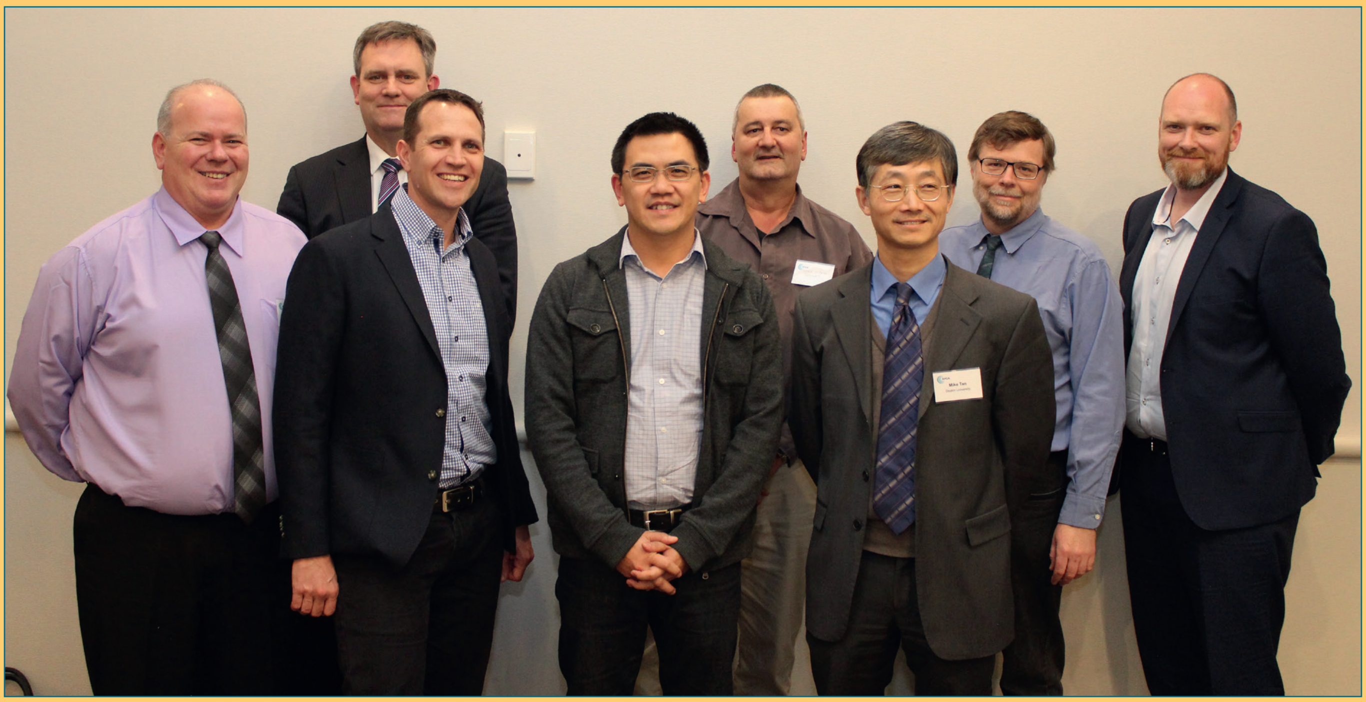
Denso Corrosion Prevention

Pipeline Corrosion Management

Tuesday 13 September Perth

APGA's Senior Policy Manager Steve Davies.

The ACA's John Grapiglia from CCE who chaired the event.



The speakers – from left to right: John Grapiglia CCE, Graham Strong CCE, Markus Seitz APA Group, Adrian Lim Rosen, Mike Tan Deakin University, Chris Cobain & Niekie Jouster Weld Net and Steve Davies AGPA.

Sponsor: International

Proudly Presented by: Australasian Corrosion Association Inc.

Corrosion Management Experiences in the Water & Wastewater Industry

22 September 2016 • Sydney

Thursday 22 September Engineers Australia, Sydney Division

39 delegates attended and thanks to our sponsor International and all our wonderful speakers:

- Greg Moore
- Andrew Martin, Kerneos
- David Johnstone, International Paint
- Brian Martin, Brian Martin & Associates
- Rob Peterson, Newcastle University
- Jim Galanos, Corrosion Control Engineering
- Matt Dafter, Hunter H20

ACA Standards Update Summary*

Welcome to the fourth corrosion related standards report for 2016.
The standards reporting for 2016 is scheduled against Technical Groups (TG) as indicated below:

Issue	2016 Standards search for TG interests
Feb	Asset Management
May	Water/Waste water (inter-alia) Material
Aug	Concrete & Cathodic Protection
Nov	Oil & Gas

This Standards report focuses on Oil and Gas in relation to corrosion.

As previously this is in two stages, namely:

1. A global standards and publication focus at **16 September 2016**, searching through SAIGLOBAL Publications at https://infostore.saiglobal.com/store, for all current publications and standards relating to corrosion of materials in the Oil & Gas industries. This is in a search for “corrosion and oil or gas”.

These results are shown under Stage 1, Search 1 and Search 2.

2. A SAI Global search, as previously, at http://www.saiglobal.com/online/ for new standards, amendments or drafts for AS, AS/NZS, EN, ANSI, ASTM, BSI, DIN, ETSI, JSA, NSAI and standards and amendments for ISO & IEC published from **14 July 2016 – 16 September 2016**, using the key words and key word groups:

- ‘durability’.
- ‘corrosion’ or ‘corrosivity’ or ‘corrosive’; but not ‘anodizing’ or ‘anodize(d)’.
- ‘paint’ or ‘coating’; but not ‘anodizing’ or ‘anodize(d)’.
- ‘galvanize’ or ‘galvanized’ or galvanizing’.
- ‘electrochemical’ or ‘electrolysis’ or ‘electroplated’.
- ‘cathode’ or ‘cathodic’.
- ‘anode’ or ‘anodic’.
- ‘corrosion’ and ‘concrete’ or ‘concrete’ and ‘coatings’.

These results are shown under Stage 2.

Summary

Stage 1

Through SAIGLOBAL Publications at https://infostore.saiglobal.com/store, for a search on ‘Corrosion and Concrete’ on 16 September 2016, there were 68 citations including:

- None form AS or AS/NZS;
- 8 from NACE;
- 3 from BSI (All BS EN);
- 2 from ISO;
- 1 from EMUR;
- 1 from Energy Institute;

Stage 2

Across SAIGLOBAL online Standards Publications there was a total of 51 listings of new Standards, Drafts and Amendments found from , 14 July 2016 – 16 September 2016; 1 Standard and 3 Drafts from AS AS/NZS being;

DR2 AS/NZS 2311:2016	Guide to the painting of buildings
DR AS/NZS 4361.1:2016	Guide to the management of paints containing lead and other hazardous metallic pigments - Industrial applications
DR AS/NZS 8124.7:2016	Safety of toys - Requirements and test methods for finger paints (ISO 8124-7:2015, MOD)
AS 1897:2016	Fasteners - Electroplated coatings

Regards,

Arthur Austin
(Arthur.Austin@alsglobal.com)

***For the full Standards Report, please visit www.corrosion.com.au**

CERTIFICATION PROGRAM

Working toward Professional Development in Corrosion

The ACA's Certification program for ACA Corrosion Technicians and Technologists recognises those with education and experience in the corrosion industry. A Corrosion Technician has at least 4 years work experience and has attended a number of formal training courses, whilst those awarded Corrosion Technologist have at least 10 years work experience and have obtained further training. For a more detailed explanation of the eligibility criteria, please consult our ACA Certification Program brochure which is available on our website www.corrosion.com.au. A schedule of current ACA Corrosion Technicians and Technologists appears below and will be published in Corrosion & Materials in each November issue and will be continuously updated on the ACA's web site. All current ACA Technicians and Technologists have been issued a wallet card with their certification number and membership details.

Please note continued membership of the ACA is a requirement for certification and therefore all certified Corrosion Technicians and Technologists will have an expiry date which coincides with their ACA membership renewal date. 'Pending' expiry dates indicate that a membership payment is overdue.

Please note this list is current as at 19 September 2016

Corrosion Technicians

Name	Cert No:	Expiry Date
Alan O'Connor	303	5/09/2017
Belinda Jones	347	21/04/2017
Ben Ward	300	Pending
Bradley Jones	258	18/04/2017
Brendan McGuinness	343	Pending
Brendan Schapers	314	5/07/2017
Christopher Butler	320	24/01/2017
Clinton Watson	341	30/06/2017
Craig Clarke	246	25/03/2017
Daniel Chambers	335	Pending
Dave Charters	261	21/01/2017
David Fairfull	179	30/06/2017
David Harley	291	17/12/2016
David Parravicini	296	2/09/2017
Gary Martin	57	Pending
Gavin Telford	244	30/06/2017
Geoff Farrant	253	30/06/2017

Corrosion Technicians

Gerrard Felix	333	Pending
Glenn Dean	280	20/01/2017
Heath Boelen	306	4/05/2017
Ian McNair	163	30/06/2017
Ian Saunders	251	24/06/2017
Justin Tanti	238	14/02/2017
Marius Gray	327	26/09/2017
Mark Watson	186	Pending
Nicholas Critchley	330	Pending
Raed El Sarraf	305	25/09/2017
Reg Oliver	223	Pending
Rodney Clarke	206	20/12/2016
Ross Darrigan	174	5/09/2017
Scott Wallbank	332	Pending
Sean Ryder	262	21/11/2016
Stephen Brown	263	4/02/2017
Venkatesh Coimbatore	192	30/06/2017
William Guest	316	14/04/2017

Corrosion Technologists		
Name	Cert No:	Expiry Date
Aaron Turner	345	19/02/2017
Adrian Dundas	250	1/02/2017
Alireza Kouklan	317	13/11/2016
Allan Sterling	191	31/03/2017
Andrew Smith	326	30/03/2017
Antonio Carnovale	203	17/12/2016
Arthur Austin	106	30/06/2017
Barry Gartner	2	30/06/2017
Bernard Egan	20	30/06/2017
Bernd Rose	252	1/05/2017
Bill Gerritsen	18	30/06/2017
Bill Lannen	111	1/01/2017
Bill McEwan	32	1/01/2017
Boris Krizman	169	17/12/2016
Brad McCoy	178	14/07/2017
Bradley Dockrill	241	15/07/2017
Brett Hollis	88	30/06/2017
Brian Byrne	27	1/01/2017
Brian Hickinbottom	138	30/06/2017
Brian Martin	60	1/01/2017
Brian Smallridge	201	30/06/2017
Bruce Ackland	82	30/06/2017
Bruce Jewell	245	10/05/2017
Bryan Cackett	70	30/06/2017
Calvin Ogilvie	17	19/01/2017
Craig Hutchinson	249	26/10/2016
Dale Franke	199	30/06/2017
Daryl McCormick	1	17/12/2016
David Nicholas	94	1/01/2017
David Scott	173	Pending
Dean Parker	108	5/07/2017
Dennis Richards	180	1/01/2017
Derek Avery	295	19/08/2017
Derek Whitcombe	325	30/06/2017
Dinesh Bankar	264	23/02/2017
Dylan Cawley	224	29/06/2017
Elio Monzu	159	30/06/2017
Erwin Gamboa	339	Pending
Frank Hewitt	67	1/01/2017
Frank Turco	309	14/04/2017
Fred Andrews-Phaedonos	153	30/06/2017
Fred Salome	231	1/01/2017
Frederick Gooder	141	30/06/2017
Garry Luskan	117	2/02/2017
Gary Brockett	215	30/06/2017
Gary Doyle	294	2/08/2017
Gary Evans	271	16/06/2017
Gavin Forrester	282	10/02/2017

Corrosion Technologists		
Gavin Richardson	48	30/06/2017
Geoff Cope	71	29/06/2017
Geoff Robb	124	30/06/2017
Geoffrey White	182	1/07/2017
Gordon Stewart	68	1/01/2017
Graeme Gummow	318	20/09/2016
Graeme Kelly	102	1/01/2017
Graham Carlisle	281	19/05/2017
Graham Sussex	136	30/06/2017
Grant Chamberlain	334	30/06/2017
Greg Moore	97	1/01/2017
Harbhajan Khera	331	Pending
Harry Lee	19	1/01/2017
Harvey Blackburn	10	1/01/2017
Ian Glover	129	30/06/2017
Ian Savage	259	14/04/2017
Ian Stewart	155	5/09/2017
Janet Morris	256	5/07/2017
Jeffrey Hurst	202	30/06/2017
Jim Galanos	254	17/12/2016
Jim Hickey	346	13/08/2017
Jim McMonagle	56	1/01/2017
Jim Steele	119	17/12/2016
John Kalis	166	17/12/2016
John Kilby	193	30/06/2017
John Lane	188	20/01/2017
John McCallum	59	30/06/2017
John Mitchell	115	30/06/2017
John Rudd	243	5/09/2017
John Waters	121	30/06/2017
John Watson	239	10/06/2017
Keith Lichti	133	30/06/2017
Kevin Woodland	323	30/10/2016
Kingsley Brown	257	30/06/2017
Leon Cordewener	44	30/06/2017
Les Boulton	43	1/01/2017
Luciano Ioan	228	30/06/2017
Luis Carro	260	30/06/2017
Mark Sigley	338	30/03/2017
Mark Weston	149	1/01/2017
Marshall Holmes	293	26/08/2017
Max Fraser	283	16/03/2017
Michael Boardman	30	12/07/2017
Michael Johnstone	230	5/09/2017
Michael Jukes	90	3/03/2017
Michael McCoy	109	14/04/2017
Mike Dinon	5	30/06/2017
Mike Slade	175	7/06/2017
Morris Young	217	30/06/2017
Murry McCormick	196	28/06/2017
Narendra Tripathi	312	30/06/2017

Corrosion Technologists		
Neil Campbell	38	30/06/2017
Nicholas Van Styn	229	25/02/2017
Nizam Yusoff	302	9/02/2017
Paul Hunter	62	30/06/2017
Paul Wilson	290	19/04/2017
Peter Crampton	8	29/06/2017
Peter Dove	210	29/03/2017
Peter Ferris	195	29/06/2017
Peter Hart	200	16/11/2017
Peter Hosford	216	1/01/2017
Peter Hunger	301	20/06/2017
Peter Wade	190	9/03/2017
Phil Harrison	145	1/01/2017
Philip Bundy	209	30/06/2017
Philip Schembri	198	17/12/2016
Raymond Da Costa	342	5/06/2017
Reg Casling	11	1/01/2017
Rob Billing	12	30/06/2017
Rob Francis	23	1/01/2017
Robert Callant	106	30/05/2017
Robert Cox	14	30/06/2017
Robert de Graaf	154	1/01/2017
Robert Freedman	147	1/01/2017
Robert Mumford	33	Pending
Rodney Wubben	46	30/06/2017
Roman Dankiw	208	29/06/2017
Ronald Tan	308	30/06/2017
Ross Antunovich	214	30/06/2017
Saeed Ali	328	15/12/2016
Stephen Holt	348	28/02/2017
Stephen Wargula	310	14/04/2017
Steve Richards	110	30/06/2017
Stuart Bayliss	236	7/11/2016
Stuart McLaughlin	299	17/12/2016
Tan Swee Hain	189	30/06/2017
Thomas Wenzel	329	Pending
Tony Betts	74	1/01/2017
Tony Murray	134	5/09/2017
Ulf Kreher	304	Pending
Verne Linkhorn	39	30/06/2017
Vic McLean	237	Pending
Wade Guye	313	9/08/2017
Wayne Burns	100	1/01/2017
Wayne Ferguson	242	4/09/2017
Wayne Speer	337	17/12/2016
William McCaffrey	142	30/06/2017
Willie Mandeno	13	1/01/2017
Xiaoda Xu	315	28/11/2016
Yongjun Tan	194	30/06/2017

PROUDLY PRESENTED BY: MAJOR SPONSOR:

Corrosion & Prevention 2016 Program

The ACA reserve the right to exclude any paper and to alter without notice any of the arrangements, timetables and programs relating to the conference. Issued: Monday 5 September 2016. # Indicates Provisional acceptance into the program.

Sunday 13 November 2016				
13.00 – 18.30	**Registration Desk Opens** Level 5 Foyer, SkyCity Convention Centre			
17.30 – 18.30	**First Time Delegates Function** *Sponsored by Galvanizers Association of Australia* SkyCity Convention Centre			
18:30 – 21:30	**Welcome Reception & Exhibition Opening** *Sponsored by Dulux Protective Coatings* New Zealand Room, Level 5, SkyCity Convention Centre			
Monday 14 November 2016				
8.30	**Conference Opening & Starting of Ed Potter Corrosion Clock** Auckland Room 1 & 2, Level 4, SkyCity Convention Centre			
9:00	**Plenary 1: Nick Laycock, Shell, Qatar** Corrosion Control in Wet Gas Pipelines Auckland Room 1 & 2, Level 4, SkyCity Convention Centre Chair: Raman Singh			
9:45	**Plenary 2: Howard Combs, Carboline, USA** Emerging Technologies for Pipeline Coatings – For Directional Drilling *Sponsored by Carboline* Auckland Room 1 & 2, Level 4, SkyCity Convention Centre Chair: Raman Singh			
10.30	Morning Tea			
	Stream A Auckland Room 1 & 2, Level 4 ***Coatings*** **Chair: Willie Mandeno**	**Stream B** Auckland Room 3 & 4, Level 4 ***Concrete /Cathodic Protection*** **Chair: Nicholas Critchley**	**Stream C** Epsom Room 1, Level 4 ***Oil & Gas*** **Chair: Graham Carlisle**	**Stream D** Epsom Room 2, Level 4 ***Research*** **Chair: Bruce Hinton**
11.00	*Confusion and Delusion in Coating Documentation* R Francis R A Francis Consulting **032**	*Using Galvanic Cathodic Protection to Repair and Protect Severely Corroded Structures* D Whitmore Vector Corrosion Technologies **046**	*Corrosion Management Planning and its Role in PIM Strategy* M Ko Quest Integrity **093**	*On the Role of Quantum Mechanics in Corrosion Processes* D Macdonald University of California, Berkeley **118**
11.30	*New Generation Coatings for Protection with Polyaspartics* R Shen Covestro **038**	*Review of the Cathodic Protection System for Wharves 4 & 5 at Port of Brisbane after 15 years of Operation* A Cheaitani Remedial Technology **039**	*New Concepts in Life Extension of Cathodic Protection Systems for Brownfield Offshore Assets* D Flanery Deepwater Australasia **108**	*Electrochemical Corrosion Behaviour of a Ni-rich Ni-Ti Alloy in 3.56wt% nacl* K Dahm Callaghan Innovation **102**
12.00	*Duplex Coatings in New Zealand: Case Studies illustrating a Durable Outcome* A Arya Galvanizers Association of Australia **104**	*Developments in Galvanic Anode Technology for Reinforced Concrete Repairs, including the latest Technological Innovations* A Sarkady BASF Australia **095**	*Visualizing Dynamic Corrosion and Coating Disbondment Processes on Simulated Pipeline Conditions* M Tan Deakin University **061**	*Effect of Microstructure in relation to Heat Affected Zone (HAZ) Corrosion of Mild Steel Welds in Marine Environments* I Chaves The University of Newcastle **034**
12.30	Lunch			
12.45	**ACA Foundation Ltd AGM** Auckland Room 3 & 4, Level 4, SkyCity Convention Centre			

	Stream A *Coatings* Chair: Dean Wall	Stream B *Concrete/Cathodic Protection* Chair: Jack Tinnea	Stream C *Oil & Gas Forum* Chairs: F Barouky & P Fleming	Stream D *Research, Education & Implementation* Chair: Kamachi Mudali
13.30	*Graphene for Durable Corrosion Resistance: Current Status and Challenges* R Singh Monash University **064**	*Preserving New Zealand's Infrastructure for the Future – Case studies showing the long term benefits of Cathodic Protection on Mounded LPG Tanks and a Wharf Structure suffering from ALWC* J Galanos Corrosion Control Engineering **163**	*Corrosion Under Insulation Inspection and Prevention Best Practice* D Lake ATTAR *Protecting Pipelines in Complex Environmental Conditions such as HDD, Shore-crossing, Stray Current Affected Areas* M Tan Deakin University	*Corrosion Behaviour of some Commercial Alloys in CO_2 Gas at High Temperature* J Zhang University of NSW **043**
14.00	*Epoxy Based Materials for Elevated Temperature end uses: What do we really Know?* M O'Keeffe AkzoNobel **075**	*Durability Risks in Buildings and Asset Protection Review and Case Studies* H Khan Parchem **020**	*MEG Corrosion Behaviour Study* V Ghodkay Curtin University *Innovative Approach to Reduce the Coating Maintenance Program Costs of Offshore Operational Plant and Structure* A Matthews Anti-Corrosion Technology Pty. Ltd.	*Adsorption and Thermodynamics Study of the Inhibition of Corrosion of Mild Steel in HCL Medium using Coconut Pulp Waste Extract* S Sobri Universiti Putra Malaysia **014**
14.30	*Chromate vs Chromate-free Primers* B Martin Defence Technology Agency **029**	*A Study of Initiation and Active Reinforcement Corrosion in Conventional Reinforced Concrete* R Melchers The University of Newcastle **052**		*The Effect of Dissolved Oxygen and Cl/NO_2 – on the Corrosion Inhibition of Sodium Nitrate in Bicarbonate/ Chloride Solution* G Eyu Queensland University of Technology **110**
15.00	Afternoon Tea			
	Stream A *Coatings Forum* Chair: Peter Dove	Stream B *Asset & Integrity Management* Chair: Johnathon Morris	Stream C *Cathodic Protection* Chair: Wayne Thomson	Stream D *Research, Water & MIC* Chair: David Nicholas
15.30	*What do we want from our PCCP?* P Dove GHD *Hazardous Coatings Removal* I Donoghue Freyssinet	*Protecting New Buildings against Corrosion – the Role of a Durability Appraisal* L Boulton Les Boulton & Associates **019**	*Registration of Impressed Current Cathodic Protection Systems with Electrolysis Committee – Learnings and Recommendations* B McGuinness Freyssinet Australia **146**	*Microbiologically Influenced Corrosion of Copper and it's Alloys – A Review* S Wade Swinburne University **084**
16.00	*AS2312 – Warranty Guidelines* T Riding Jotun	*Remanufacturing Corrosion Control Coatings* M Haselkorn Rochester Institute of Technology **123**	*Offshore Wind Monopile Foundations - Internal Corrosion Mitigation by Cathodic Protection* R Jacob The CP Consultancy **021**	*Microbiologically Influenced Corrosion in Wastewater Treatment Plants* S Furman AECOM **145**
16.30	*Fire Proofing in the New Zealand Building Industry* G Moran Carboline	*Life Extension of Reactor Internals by Modern Weld Techniques* R Collier Ballance Agri-Nutrients **124**	*An Overview of Finite Element Models used for CP Applications* F Varela Deakin University **083**	*Identification in Bacterial Types in various Atmospheric Corrosion Sites using Standard Test Kits* R Jeffrey The University of Newcastle **031**
17.00			*# Impressed Current Cathodic Protection to a Prestressed Concrete Structure – Ten Years of Success* M Ali GHD **154**	*Case Studies of Sleeved Ductile Iron Pipe Assessments* M Dafter Hunter H_2O **023**
18.30 – 21.30	**Young Corrosion Group Event** *Sponsored by Galvanizers Association of Australia* The Bluestone Room, 9-11 Durham Ln, Auckland			

Tuesday 15 November 2016

9.00	**Plenary 3 - PF Thompson Lecture: Patricia Shaw, BRANZ, New Zealand** Corrosion of Polymeric Materials Auckland Room 1 & 2, Level 4, SkyCity Convention Centre Chair: Brian Hickinbottom
9.45	**Plenary 4: Digby Macdonald, Departments of Nuclear Engineering & Materials Science and Engineering, University of California, USA** Photo-Electrochemical Study of the Passive State Auckland Room 1 & 2, Level 4, SkyCity Convention Centre Chair: Brian Hickinbottom
10.30	Morning Tea

	Stream A	Stream B	Stream C	Stream D
	Stream A Auckland Room 1 & 2, Level 4 *Materials Selection & Design* Chair: Patricia Shaw	**Stream B Auckland Room 3 & 4, Level 4 *Concrete Corrosion & Repair* Chair: Frank Collins**	**Stream C Epsom Room 1, Level 4 *Asset Management* Chair: Tracey Sherman**	**Stream D Epsom Room 2, Level 4 *Research* Chair: Ian MacLeod**
11.00	*Using Intumescent Coatings to Achieve Building Code Compliance on Steel Structures* C Partington AkzoNobel **015**	*Corrosion Control of Alaskan Bridges* J Tinnea Tinnea & Associates **121**	*Live Transmission Line Corrosion Surveying* D Lake ATTAR **155**	*Application of the STEM Program to Corrosion Engineering* G Keller OSD/LMI **059**
11.30	*Ropes-Degradation of Natural, Synthetic and Steel Wire Products* A James Defence Technology Agency **026**	*Hybrid Corrosion Protection Reinforced Concrete Structures* G Glass Concrete Preservation Technologies **164**	*The Effects of Light Rail Systems on Underground Assets* J Grapiglia Corrosion Control Engineering **033**	*EIS and Mott-Schottky to Study the Passive Film Properties of 316L and its Susceptibility to Pitting Corrosion in CO_2 Environments* Y Abdulwahhab Curtin University **144**
12.00	*Coastal Residence Constructed from Weathering Steel* W Mandeno Opus International Consultants **126**	*Acidification Induced Deterioration of Concrete Cathodic Protection Systems and its Management* W Green Vinsi Partners Consulting Engineers **115**	*Corrosion of Underground Vehicle Diesel Exhaust Scrubber Tanks* S Krismer Bureau Veritas **096**	*Assessing Hydrogen Embrittlement Susceptibility of Automotive MS-AHSS using the Linearly Increasing Stress Test* J Venezuela University of Queensland **140**
12.30	Lunch			
	Stream A *Coatings* Chair: Ricky Collins	**Stream B *Concrete Forum* Chairs: W Green & F Blin**	**Stream C *Asset Management* Chair: Raed El Sarraf**	**Stream D *Mechanisms, Modelling & Prediction* Chair: David Williams**
13.30	*Refurbishment of Makatote Viaduct, New Zealand* G Matthews TBS Group **139**	*An Independent Consultant's Experiences & Experiences in the US with Electrochemical Treatments of Concrete* J Tinnea Tinnea & Associates	*Online Asset Management and Operational Optimisation through Online Integrity Monitoring* J Grapiglia Corrosion Control Engineering **008**	*The Use and Mis-Use of the Tafel Equation in Corrosion Science* A Betts Dublin Institute of Technology **080**
14.00	*Corrosion Studies on Surface Treated Tialn and Alcrn Coatings in 3.5% Nacl* L Ward RMIT University **090**	*Experiences Various with Hybrid Treatment of Concrete* G Glass Concrete Preservation Technologies *Experiences Various with Galvanic Anode Treatment of Concrete* D Whitmore Vector Corrosion	*Mitigating Corrosion under Insulation in a Gas Processing Facility 10 years on* M O'Keeffe AkzoNobel **077**	*Corrosion of Copper Alloys on Historic Shipwrecks and Materials Performance* I MacLeod Western Australian Maritime Museum **105**
14.30	*Capabilities and Limitations of Direct Current and Electrochemical Impedance Mapping In Measuring Cathodic Disbondment of Coatings using Multi-Electrode Array* F Mahdavi Deakin University **166**		*Corrosion Investigation and Repair of a Corrugated Aluminium Highway Culvert* W Mandeno Opus International Consultants **125**	*Materials within New Zealand Geothermal Environments* Z Li BRANZ **113**
15.00	Afternoon Tea			
	Stream A *Contractor Forum* Chair: Justin Rigby	**Stream B *Concrete* Chair: Gareth Glass**	**Stream C *Asset Management & Defence* Chair: Les Boulton**	**Stream D *Research & Research Forum* Chair: Timothy Koo**
15.30	*How do we Introduce Painter Training?* P Dove GHD	*Service Life Prediction of Reinforced Concrete Exposed to Marine Water* L Aldridge Deakin University **103**	*Corrosion Based Reliability Centred Maintenance on a MRH 90 Helicopter* S Russo QinetiQ **165**	*Long-Term Pitting Corrosion of 6060 Aluminium Alloy Immersed in Natural Seawater* M Liang The University of Newcastle **070**
16.00	*How Contractors & Consultants can Collaborate to Select and Specify the Optimum Corrosion Protection System* R El Sarraf Opus International Consultants	*Long Term Structural Health Monitoring of a Structure Deteriorating due to Chloride Induced Corrosion* S Connolly BG&E Materials Technology **040**	*Atmospheric Corrosivity of RNZAF Airbases* B Withy Defence Technology Agency **028**	**Research Forum** *Growing the Research Technical Group* *Advances in Corrosion Research*
16.30	*Contractor Engagement with the ACA and its Members* J Rigby REMEDY Asset Protection	*Service Life Extension of State Highway 16 Bridges – New Zealand's First Hybrid Corrosion Protection Application* C Christodoulou AECOM **065**	*Influence of Corrosion Products on Localized Corrosion of Carbon Steel in Natural Seawater* AM Grolleau DCNS Research **074**	*Corrosion Research Discussion* *Research & Applied Industry Technologies / Other Issues*
19.00 – 24.00	**ACA Annual Awards Dinner** *Sponsored by Denso Australia* The Langham Auckland, 83 Symonds St, Grafton, Auckland			

Wednesday 16 November 2016				
	Stream A **Auckland Room 1 & 2, Level 4** ***Asset Management*** **Chair: Ron Berry**	**Stream B** **Auckland Room 3 & 4, Level 4** ***Mechanisms, Modelling & Prediction*** **Chair: Scott Wade**	**Stream C** **Epsom Room 1, Level 4** ***Cathodic Protection Forum*** **Chair: Mark Sigley**	**Stream D** **Epsom Room 2, Level 4** ***Research*** **Chair: John Duncan**
9.30	*The Role of Corrosion Management in Asset Management* J Morris Opus International Consultants **082**	*Agar as an Analogue for Soil in Corrosion Studies: Where to Next?* A Spark CSIRO & RMIT University **068**	*CP and Stray Current Management in NZ* M Sigley FirstGas	*Green Rare Earth Compounds as Corrosion Inhibitors for Steel* A Somers Deakin University **141**
10.00	*Asset Management against Corrosion, Transpower New Zealand* S Horn Transpower **156**	*Romanoff's Soil Corrosion Data Deconstructed* R Melchers The University of Newcastle **053**	*CP Registration Regulations* P Wade Energy Safe Victoria *Stray Current Corrosion Acceptance Criteria for Reinforcement in Concrete – which Standard to follow?* M Ali GHD	*Corrosion Inhibition Assessment of Marine Grade Al Alloys using a Rapid Screening Technique* L Ward RMIT University **085**
10.30	*External Threats and Internal Opportunities: Two Cases of Firms' Growth in the New Zealand Corrosion and Prevention Industry* W Thomson Anode Engineering **069**	*The Corrosion of Stainless Steel Components in Aggressive Water Environments* R Jeffrey The University of Newcastle **017**	*The Monitoring and Assessment of Cathodic Protection Levels on Combined Onshore and Offshore Pipelines Permanently Connected to Sacrificial Anodes* J Grapiglia Corrosion Control Engineering	*Low-Alloy Steel in Near-Neutral pH Underground Conditions* I Gadala The University of British Columbia **111**
11.00	Morning Tea			
11.30	**Sandy Williamson, NACE International** Results of the International Measures of Prevention, Application and Economics of Corrosion Technologies (IMPACT) Study Auckland Room 1 & 2, Level 4, SkyCity Convention Centre Chair: Brad Dockrill			
12.15	**Plenary 5: David Williams, University of Auckland** Advancement of Corrosion Science through New Experimental Methods Auckland Room 1 & 2, Level 4, SkyCity Convention Centre Chair: Brad Dockrill			
13.00	Lunch			
	Stream A ***Asset Management Forum*** **Chair: Mike Boardman**	**Stream B** ***Concrete*** **Chair: Paul Vince**	**Stream C** ***Cathodic Protection*** **Chair: Brian Martin**	**Stream D** ***Research*** **Chair: Rob Melchers**
14.00	**Asset Management Forum** w/ Asset Management Council Chair: Mike Boardman *ISO55000 and How it Relates to Industry and the AM Council Models* Martin Kerr Asset Management Council *The Use of Cementitious Coatings to Reinstate Low Nominal Cover on Reinforced Concrete Structures* David Johnstone International Paint *Case Studies in Corrosion Management* Raed El Sarraf Opus *Asset Management from the Perspective of Corrosion* James Boyce Broadspectrum International	*Concrete Corrosion Damage Modelling in 3D* F Collins Deakin University **042**	*Application of 'Smart' TR Technology to Reduce Installation and Operating Costs of Impressed Current CP Systems in Long Structures* D Celine Omniflex **153**	*Relationship between Microstructure and Elemental Segregation to the Long-Term Corrosion Performance of Cast Iron Water Pipes* D Nicholas Nicholas Corrosion **016**
14.30		*Effect of Pore Characteristics and Chloride Binding on Time-Dependent Chloride Diffusion into Cementitious Material* L Aldridge Deakin University **089**	*An Overview on Cathodic Shielding Produced by Disbonded Coatings* M Latino Deakin University **060**	*The Electrokinetics of Magnesium - Active and Passive Corrosion States* H Flitt Queensland University of Technology **078**
15.00		*The use of Cementitious Coatings to re-line Old Concrete, Brick Manholes and Sewer Structures* D Johnstone AkzoNobel **119**	*Major Wharf Rehabilitation – A Case Study of the Construction Methods and Practices Utilised to Safeguard Ongoing Structure Durability* N Critchley Freyssinet Australia **094**	*Factors Involved in the Long-Term Corrosion of Buried Cast Iron* R Petersen The University of Newcastle **067**
15.30			*Retrofitting Impressed Current Cathodic Protection to an Existing MSCL Water Network in Metropolitan Melbourne* C Blackney, D O'Keefe Select Solutions **063**	*Extreme Value Analysis of Carbon Steel Pitting Corrosion under Deoxygenated Seawater* X Wang University of Newcastle **071**
16.00 – 16.30	**Closing Session** Auckland Room 1 & 2, Level 4, SkyCity Convention Centre			
16.30 – 18.30	**Farewell Function** *Sponsored by Les Boulton & Associates* Bar 21, SkyCity LB &A LES BOULTON & ASSOCIATES LTD			

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Wednesday 16 November | Auckland | Sky City, Auckland Rooms 1 & 2

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Attendees will have the opportunity to walk through a 62 booth exhibition to meet with product and service suppliers in the corrosion management industry, as well as have the option to attend peer reviewed presentations that form part of the Technical Program of the Corrosion & Prevention conference.

Cost: $350
includes lunch

Full Day Program:

- **9.30am:** The Role of Corrosion Management in Asset Management, Jonathan Morris, Opus International Consultants
- **10.00am:** Asset Management against Corrosion, Transpower New Zealand, Stephen Horn, Transpower
- **10.30am:** External Threats and Internal Opportunities: Two Cases of Firms' Growth in the New Zealand Corrosion and Prevention Industry, Wayne Thomson, Anode Engineering
- **11.00am:** Morning Tea (in the 62 booth exhibition)
- **11.30am:** Results of the International Measures of Prevention, Application and Economics of Corrosion Technologies (IMPACT) Study, Sandy Williamson, NACE International
- **12.15pm:** Advancement of Corrosion Science through New Experimental Methods, David Williams, University of Auckland
- **1.00pm:** Lunch (in the 62 booth exhibition)
- **2.00pm:** ISO55000 and How it Relates to Industry and the AM Council Models, Martin Kerr, Asset Management Council
- **2.30pm:** The Use of Cementitious Coatings to Reinstate Low Nominal Cover on Reinforced Concrete Structures, David Johnstone, International Paint
- **3.00pm:** Case Studies in Corrosion Management, Raed El Sarraf, Opus International Consultants
- **3.30pm:** Asset Management from a Perspective of Corrosion, James Boyce, Broadspectrum

OR

Cost: $50
includes lunch

2 hr Asset Management Forum:

- **1.00pm:** Lunch (in the 62 booth exhibition)
- **2.00pm:** ISO55000 and How it Relates to Industry and the AM Council Models, Martin Kerr, Asset Management Council
- **2.30pm:** The Use of Cementitious Coatings to Reinstate Low Nominal Cover on Reinforced Concrete Structures, David Johnstone, International Paint
- **3.00pm:** Case Studies in Corrosion Management, Raed El Sarraf, Opus International Consultants
- **3.30pm:** Asset Management from a Perspective of Corrosion, James Boyce, Broadspectrum

These Asset Management Forum Events are a part of:

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13–16 November
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3D Scanning Meets Ultrasonic Technology

NDT inspectors can now produce more reliable and efficient pipeline evaluations than ever before by combining Ultrasonic Thickness (UT) measurements - with 3D scan data. Most UT systems including Sonatest's Masterscan D70, Veo+ or even conventional thickness gauges can now be combined with 3D scans from Creaform's HandySCAN 3D scanner by using Pipecheck pipeline integrity assessment software. Perform safer pipeline integrity assessments with Sonatest and Creaform.

The Masterscan D-70 is the leading flaw detector in its class. This instrument offers a fully capable and functional set of tools and software for inspection across all applications. Capabilities include encoded B-Scan, Advanced Thickness logging and Dryscan capability in a portable and field upgradeable enclosure.

Using the UTility Lite software provided, inspectors have the tools readily available to manage inspection data as well as creating files for use in other applications such as Pipecheck.

The new Sonatest Veo+ is a Phased Array Digital Flaw Detector, which, when combined with a suitable probe such as the Sonatest WP2 Wheelprobe, can produce a high resolution C-Scan, allowing for increased analysis of the inner surface of the pipe. Using UTStudio software provided with the Veo+ scan data can be easily exported for reporting, or into a format that can be easily combined with 3D scan data.

By utilising Creaform's Handyscan700 3D Scanner, a complete 3D surface map of the pipe is scanned directly into the Pipecheck software. True wall thickness assessment can then be made as Pipecheck combines the Masterscan UT data, or Veo C-Scan data with the 3D surface scan data for a reliable visualization and an optimal understanding of the pipeline's anomalies. By combining the results of the best NDT equipment for assessing both the inside and the outside lining of a pipeline, Pipecheck takes into account the interaction of the internal and external deterioration to calculate pipeline burst pressures.

Pipecheck can also be used with the UT data only to provide burst pressure calculations quickly and easily without the inclusion of 3D scan data.

RFS are Supporting Sponsors and will be exhibiting on stand #29 at the Corrosion & Prevention conference, 13-16 November 2016 in Auckland, New Zealand.

For more information contact Russell Fraser Sales today:

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E: rfs@rfsales.com.au
Web: www.rfsales.com.au

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EXHIBITORS

3C Corrosion Control Company

www.3ccc.se

Stand Numbers: 54 & 59

Corrosion Control Company (3C) was founded 1996 in Sweden. 3C is a highly specialized company with extensive know-how in cathodic protection in general and sea water application in particular with a strong international focus. 3C have strategic partners in Middle East, South East Asia and Australia.

Our main focus areas are Power Generation, Oil & Gas and Desalination industries. Beside of our standard products such as the Thor rectifier and Monitoring system we shall display our latest patented system for protection of pumps and pipes in desalination plants 3C has developed a range of products for cathodic protection such as Switch Mode rectifiers, automatic and remote control and monitoring systems, customized MMO anodes and probes for AC corrosion detection.3C are member of international originations such as ACA, NACE, CeoCor and ICorr.

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Email: bjorn.lindell@3ccc.se

A&E Systems

www.ae-sys.com

Stand Number: 05

The A&E Group manufactures and supplies Alocit and Enviropeel products, providing a unique range of environmentally friendly anti-corrosion systems. The Alocit 28 Series range of two-pack, zero-VOC, epoxy coatings is well known for its ease of use and durability both above and underwater whilst Enviropeel, a sprayable, removable and reusable thermoplastic barrier coating system, is revolutionising corrosion protection with its ability to protect important assets for up to 75 years in the harshest environments.

Chris Harrey
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Email: chrisharrey@ae-sys.com

Advanced Nano Solutions

www.AdvancedNanoSolutions.com

Stand Number: 24

Advanced Nano Solutions (ANS) provides Microbial Influenced Corrosion (MIC) protection to a wide range of industrial environments. ANS is committed to helping prevent harmful bacteria from causing damage and harm in healthcare facilities, water systems, oilfield infrastructure, food and beverage preparation facilities, marine environments, and many other industries. Our proprietary Antibacterial Nano Alloy (ANA) can be applied directly on a variety of surfaces or can be tailored as an additive to existing coatings and paints and ANA can be used in extreme temperatures and exhibits exceptional abrasion resistance.

Kelly Jones, President
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Email: kjones@advancednanosolutions.com

AEGIS

www.aegis.net.au

Stand Number: 46

For more than 80 years Aegis has designed and manufactured test equipment for utility companies worldwide. Aegis strives to maximise the life of a utility network, seeking continuous reliable operation and performance.

From contractors to network owners, Aegis provides test and measurement solutions for daily use.

Aegis is transforming the corrosion protection industry by providing 24/7 monitoring of your protection systems. You no longer need to wonder whether your network is being protected, let the DataCell product range do it for you.

The analysis of your data can be done while on the move via tablet or mobile or at the office, react to alarms only as required, and proactively maintain your asset efficiently.

Matthew Mitchell, Steve Watt or Frank Armijo
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Airblast Australia

www.airblastaustralia.com.au or www.blastrac.com.au

Stand Number: 22

For more than 40 years, Airblast has been the world leader in providing blasting and painting solutions to the anticorrosion industry. With an unparalleled network of offices around the world Airblast works closely with our customers and distribution partners providing field proven equipment as well as developing customised solutions for your specific application. With world class products come class leading solutions, with an unparalleled arsenal of surface treatment products including, Airblast Abrasives, Airblast blast room facilities, Airblast high production wheel blasting machines, Dust management, abrasive recycling, Blastrac grinding/scarifying and Graco.

With branches and Agents located across the country ready to help with all your surface preparation and coating application solutions, we have the best products to achieve the best results.

David Pocock or Ian Beets - Blastrac Surface Prep Equipment
Phone: +61 8 9271 2265 or +61 407 945 694
Email: david@airblastwa.com.au or ian.beets@blastrac.com.au

Air Solutions

www.air-solutions.co.nz

Stand Number: 06

Air Solutions specialises in delivering bespoke air treatment solutions for a wide-range of industries. We are recognised for setting the standards for complete customer satisfaction, starting with; selection, design, installation and service of our humidifier and dehumidifier systems.

Our experience and technical expertise help us to deliver the best results for our clients' humidity control requirements. We will work with you to deliver a customised solution that will meet your requirements, on time and suit your budget.

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Anode Engineering

www.anodeengineering.com

Stand Number: 03

Anode Engineering Pty Ltd is a specialist product and service provider to the wider New Zealand and Australian asset integrity industry. Our long standing association with the industry has seen us develop relationships and corresponding expertise in providing cutting edge products, services and technology in corrosion management and prevention. With offices in Auckland, Wellington, Brisbane and Melbourne our team are able to lead the industry in design, installation, commissioning and management of:

• Anodes • CP Systems, Instrumentation & Materials • Coating Assessment, Equipment & Services • Survey Services and Equipment • Remote Monitoring Systems • Corrosion Monitoring • Earthing/Surge Equipment • CP Backfills • Exothermic Welding • Holiday Detectors • MIJ's and Flange Isolation • Pile Protection & Anti-Fouling • Nut and Bolt Protection • Staff Training • Swain Meters • Thermoelectric Generators (TEGs) • Vapour Phase Corrosion Inhibitors

Wayne Thomson, Managing Director
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Email: sales@anodeengineering.com

Anti Corrosion Technology

www.anticorrosiontechnology.com

Stand Number: 53

Anti Corrosion Technology (ACT) is an Australian-based engineering company that specializes in providing sustainable solutions in materials engineering and corrosion control by senior specialists for the oil & gas, water, mining, marine and power generation industries. ACT is also the authorised and sole distributor of STOPAQ systems in New Zealand and Australia offering unique and cost effective solutions for external pipeline corrosion protection including field joint coating, factory applied mainline coating, flange and valve protection, HDD, steel pipe casings under road & rail crossings as well as corrosion protection of tank bottoms and offshore/ submerged structures such as platform risers, wharf piles and jacket legs.

Simon Ghobrial, Managing Director
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Email: info@anticorrosiontechnology.com

ARDEX Australia & New Zealand

ardexaustralia.com or ardex.co.nz

Stand Number: 13

For more than 60 years, ARDEX has been the quality leader for an entire industry, offering excellent building chemicals with supreme processing reliability – the brand of choice for installers and wholesalers.

Our waterproofing and general construction solutions are highly application specific. From sub-floor to roofing, we have developed products that stand the test of time – and moisture. Non-failure in these areas, even under extreme conditions, is critical which is why so many professionals rely on ARDEX.

Danny Ruch, Marketing Category Specialist - Construction & Remedial or Will Brettell, Product Manager - Waterproofing

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Email: danny.ruch@ardexaustralia.com or william.brettell@ardexnz.com

BASF Australia

www.master-builders-solutions.basf.com.au

Stand Number: 47

BASF's Construction Chemicals division offers advanced chemicals solutions for new construction, maintenance, repair and renovation of structures: Our comprehensive portfolio encompasses concrete admixtures, cement additives, chemical solutions for underground construction, waterproofing systems, sealants, concrete repair & protection systems, performance grouts, performance flooring systems, tile fixing systems, expansion control systems and wood protection solutions.

To solve our customers' specific construction challenges from conception through to completion of a project, we combine our know-how across areas of expertise and regions and draw on the experience gained in countless construction projects worldwide.

Andrew Sarkady
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BBR Contech

www.contech.co.nz

Stand Number: 61

BBR Contech is a leading provider of specialist contracting services related to post-tensioning and concrete strengthening, protection and repair for New Zealand's construction and civil engineering industry.

Established over 50 years ago, BBR Contech offer unrivalled expertise. We work with a wide range of clients, consultants and contractors on a huge variety of projects ranging from commercial, industrial and community buildings to wharves, dams, bridges, highways, car parks, hangars, hotels, water-treatment plants and more. Our team of qualified and experienced specialists has an outstanding record of success and deliver results in some of the most complex and challenging environments.

Rhys Rogers
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Email: RRogers@contech.co.nz

Blastquip / BlastOne

www.blastquip.com or www.blastone.com.au

Stand Numbers: 20 & 21

Blastquip has been a Specialist Supplier of Equipment and Abrasives to the Protective Coatings and Corrosion Control Industry for over 35 years. Our connection to BlastOne International gives access to global experience combined with continual research and advancement programs enables us to provide technical advice to achieve the most cost effective surface preparation and coating solution. We supply the complete solution to the industry, from custom designed Blast Rooms and Paint Booths to Specialist Coating Inspection and Certification Instruments

You can count on us for a large range of high quality products in stock, friendly highly trained staff, excellent service and free technical advice.

Jodie Ivory
Phone: Toll Free Aust. 1800 882 229
or free call NZ 0800 100 493

Blygold Oceania

www.blygold.com.au

Stand Number: 09

Blygold prevents and stops corrosion in air conditioning systems with our unique anti-corrosion coating products. Blygold Oceania is part of Blygold International, which has been established for over 36 years with a reputation for excellence and quality of products and services. Blygold services many clients such as offices, retail, airports, hospitals, hotels, and many industries.

Benefits Blygold treatment:

- save up to 20% on energy
- double the lifespan
- increase reliability
- provide cleaner air

Specifications Blygold treatment:

- salt and acid resistant over 4000 hours
- coating 25 to 30 microns
- full coverage, fins and the copper tubes plus the connection between the fins and tubes
- metal pigmentation, conductivity stays high
- can be applied and maintained on site

Mark Weir, Managing Director
Phone: 1300 271 115 (Australia only)
or +61 7 3807 0660 (International)
Email: admin@blygold.com.au

Bristle Blaster Australia

www.bristleblaster.com.au

Stand Numbers: 48, 49 & 50

Bristle Blaster® Australia Pty Ltd is the proud Monti Partner for Australia, New Zealand, Papua New Guinea and New Caledonia. Monti is the manufacturer of Bristle Blaster® Surface Preparation Technologies.

Bristle Blaster® Australia Pty Ltd supplies and supports the Bristle Blaster® throughout a variety of industries, including pipeline, oil & gas, marine / shipyards, bridge maintenance, mining and construction, to mention a few. Based in Melbourne, we work closely with select local partners throughout the region to provide on-site service, training and support.

For all New Zealand enquiries please contact our New Zealand Partner, Syntech Distributors Ltd on +64 9820 2121 or alternatively contact the team at Bristle Blaster® Australia today to find out more about products and services.

Phil Chester, Managing Director
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Email: info@bristleblaster.com.au

Carboline

www.carbolinenz.co.nz

Stand Numbers: 30 & 31

Carboline is dedicated to supplying high performance coatings, linings and fireproofing products around the world through continuous technological improvements and superior service.

Our commitment to provide excellence in service and in product means our customers have access to the best possible coatings and solutions for superior corrosion and asset protection.

Altex Coatings is part of the Carboline global network. Since 1954 Altex has become one of the largest privately owned manufacturers of high performance coatings in Australasia. Supplying a wide range of coating types and systems for almost every major industry sector, with a strong focus in technology, training, staff and customer education. Altex Coatings Limited is a Resene Group company.

Ricky Collins
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Email: ricky@carboline.co.nz

Cathodic Protection Co

www.cathodic.co.uk

Stand Number: 58

Cathodic Protection Co Ltd, founded in 1950, is a global organisation and one of the first companies in the UK established specifically to provide equipment and engineering services for the cathodic protection of pipelines, storage tanks, well casings, steel in concrete and marine structures for the oil, gas, petrochemical, water and power industries. With clients worldwide, our NACE and iCorr qualified engineers provide a full design, project management and procurement service for CP applications, as well as site survey services, consultation and training. We also specialise in the design, manufacture, supply, installation and commissioning of Cuprion® automatic marine anti-fouling systems.

Contact: Ed Sparks, Sales Manager
Phone: +44 1476 590 666
Email: cpc@cathodic.co.uk

CERAMISPHERE

www.ceramisphere.com

Stand Number: 07

Ceramisphere is a micro-encapsulation company based in Sydney Australia. We are manufacturing a new type of smart anticorrosive pigment: Inhibispheres™. Our range of products are novel controlled release corrosion inhibitors designed to work to protect assets in all kinds of environments. This innovative and patented technology brings a range of unique benefits: the simplification of the paint system, the ability to formulate inhibitors incompatible with the paint, and extension of the corrosion protection in time. In addition, the Inhibispheres™ are very easy to incorporate in a wide range of paint formulations with no impact on the final paint properties.

Andrew (Andy) Noble, Coating Formulation Specialist
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Email: andynoble@ceramisphere.com

Corrosion Control Engineering

www.cceng.com.au www.cceng.co.nz

Stand Number: 36

Corrosion Control Engineering (CCE) is Australasia's leading Cathodic Protection specialist. CCE has 7 offices throughout Australia and New Zealand that are managed by Principal Engineers, each of whom have in excess of 30 years' experience in the corrosion control industry.

The CCE team consists of qualified professional engineers and technicians who have specialised in the field of corrosion mitigation and Cathodic Protection for many years, and who are certified with the ACA and/or NACE International. CCE also supplies a wide range of CP and pipeline related products and materials to the industry.

CCE specialises in the design, supply, installation and monitoring of cathodic protection systems for:

- Pipelines & Facilities
- Ports, wharves and jetties
- Storage tanks
- Mine sites
- Steel reinforced concrete
- Marine vessels
- Offshore structures

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Decora Group

www.decora.co.nz

Stand Number: 42

The Decora Group has been manufacturing and distributing anti corrosive coatings for over 30 years. Located in Auckland, New Zealand the manufacturing facility produces an extensive range of decorative and industrial coatings. It is ISO 9001 and APAS certified, assuring quality coatings are produced to the most stringent quality control standards.

The Decora Group distributes ZRC and the Camrex Camovin range of anti-corrosive coatings to Australia, New Zealand and the Pacific Islands. For over 30 years our industry leading anti-corrosive coatings have been specified by architects and engineers for thousands of corrosion protection projects.

The Decora Group offers superior service, experienced technical back up, combined with industry leading product performance for extended longevity of corrosion protection.

Derek McClelland
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Denso New Zealand

www.densoaustralia.com.au

Stand Numbers: 32 & 33

Preventing the spread of corrosion

Denso Australia is an industry leader in corrosion prevention and sealing technology and has been manufacturing and supplying corrosion prevention solutions to the Australian market since 1961.

The Denso range of brands are globally recognised which include:

- Protal • PCS • SeaShield • Denso
- Archo Rigidon • Densostrip • Sylglas

Denso's extensive product range is suitable for use in a wide range of highly corrosive environments with operating temperatures ranging from sub-zero to 250°C, across the pipeline, marine, tanking and structural markets. Systems are tailor made for individual anti-corrosion and sealing solutions developed with the realities of an on-site application in mind.

Denso will be showcasing a range of anti-corrosion and abrasive resistant product lines developed for the pipeline, marine, structural and distribution markets. For more information on Denso's products and services visit www.densoaustralia.com.au

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Direct Connections

www.directconnections.com.au

Stand Number: 56

Direct Connections is an innovative R&D company, designing and manufacturing equipment to support the corrosion mitigation industry.

We have engineered and produced numerous devices, although our main focus has been on Dataloggers for monitoring CP Systems.

Our new range of BLE Loggers allows unsurpassed flexibility with wireless control, using Smartphones, Tablets, Laptops, or even remote monitoring from anywhere in the world.

Minimising maintenance costs and down-time, the dataloggers are totally field-serviceable and field-calibratable. Their IP67 rated enclosure permits effortless access to the standard AA alkaline batteries, which power the datalogger's continual use for 2 – 4 years.

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Dulux Powder & Industrial Coatings (Kulorthene)

www.kulorthene.com

Stand Number: 57

Kulorthene Thermoplastic Coating from Dulux is a High performance thermoplastic system which resists most severe environmental conditions - with one coat application.

Steel protected by a single coat of Kulorthene Abcite provides a cost effective corrosion solution. A single coat of Kulorthene Abcite can be applied between 400-1000 microns which makes the process and turn around much faster than multiple wet paint systems.

Kulorthene Abcite 1060/X60, meets the requirements for corrosion protection of class C5-M High (Offshore and Marine) and Im3 High (Underground) ISO 12944-6 and has proved its worth for many years under these conditions. Kulorthene Abcite has been used in a wide variety of environments. Case studies in New Zealand include applications as diverse as Drinking Water Pipes for Super Yachts, Potable Water Valves and Fittings, Steel Reinforcement Bars and Dairy Processing Plants.

Andrew Allan, Business Sector Manager (Thermoplastics)
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Email: andrew.allan@dulux.co.nz

Dulux Protective Coatings

www.duluxprotectivecoatings.com.au

Stand Number: 28

For over 80 years, Dulux Protective Coatings provides protection against corrosion, chemical attack, abrasion and impact damage in diverse, harsh and corrosive environments with our broad range of products. Heavy duty inorganic zinc silicate and zinc-rich epoxy primers, high build epoxies, chlorinated rubbers, epoxy-acrylic and polyurethane topcoats, micaceous iron oxide coatings, polyurea and heat resisting product lines are available from over 230 outlets across Australasia.

Dulux Protective Coatings' experience provides tailor made solutions for whatever your project demands, even for highly corrosive and difficult conditions.

Contact your Dulux Protective Coatings Representative or Dulux Customer Service on 13 23 77 or via www.duluxprotectivecoatings.com.au.

Judy Knapp, Marketing Communications Manager
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Email: judy.knapp@dulux.com.au

Freyssinet Australia

www.freyssinet.com.au

Stand Numbers: 25 & 26

Freyssinet in Australia & New Zealand are subsidiaries of the Soletanche Freyssinet Group which operates in over 100 countries spanning 5 continents. Freyssinet provide solutions for specialised civil and remedial engineering and structure post tensioning. Through its commitment to Sustainable Technology, we deliver effective and durable results using local expertise, teamed with proven solutions and innovative technologies.

Tom Wenzel, National Remedial Team
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Email: twenzel@freyssinet.com.au

G Squared Solutions

www.g2sol.com.au

Stand Number: 55

We provide specialist consultancy in cathodic protection and electrical hazard mitigation. Our clients are water, gas and petrochemical industry pipeline authorities, and engineering companies.

Our services include site investigation, field survey data gathering, analysis and design of cathodic protection and hazardous voltage mitigation systems. We perform end to end reviews of pipeline protection systems and assist authorities to review and refine their in house specifications for improved pipeline monitoring and protection.

Employing advanced Geographical Information System GIS and specialised software we are capable of modelling soil layer stratification, stray current potential gradients, cathodic protection attenuation, and Low Frequency Induction LFI.

Graeme Gummow
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Email: graeme.gummow@g2sol.com.au

Galvanizing Association of New Zealand & Galvanizers Association of Australia

www.galvanizing.org.nz & www.gaa.com.au

Stand Number: 51

The Galvanizing Association of New Zealand (GANZ) and Galvanizers Association of Australia (GAA) represent all major hot dip galvanizers in New Zealand and Australia. The associations work together to promote existing and new uses of hot dip galvanizing to end-users and specifiers, to encourage constant improvement in the environmental practices of its members, and to circulate knowledge of the process to fabricators and engineers.

The Associations provide free technical publications and information on all aspects of hot dip galvanizing; including the process, application, durability, design and painting of hot dip galvanized steel.

John Notley, Chairman (GANZ)
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Email: enquiry@galvanizing.org.nz

HEMPEL

www.hempel.com

Stand Number: 08

Hempel is a world-leading supplier of protective coatings for the marine, protective, container, yacht and decorative segments. Our goal is to increase the long-term value of our customers' assets by providing them with coatings that help extend product lifetimes and reduce maintenance costs. At Hempel, 'quality' is a promise we deliver every day, and have been for over 100 years. This means not only satisfying our customers' market needs with dependable and innovative solutions, but also maintaining their commitment to international standards of excellence.

Peter Florence
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Email: pefl@hempel.com

Industrial Minerals (NZ)

www.mineralscorp.com

Stand Number: 02

Freephone NZ 0800 646 372
Freephone AU 1800 309 734
www.mineralscorp.com

Established 23 years ago, Industrial Minerals (NZ) Ltd is a leading supplier of high quality, high performing products, including an extensive range of blasting abrasives, blasting equipment and dustless surface preparation equipment that have been industry proven throughout the world. Industrial Minerals (NZ) Ltd is a distributor for the following products:

- Super Garnet
- Max Blast Garnet
- EcoQuip® 2 Vapor Abrasive® Blast Equipment
- Ibix® Portable Blast Equipment
- Novatek™ Corporation Dustless Surface Preparation Equipment
- Clemco Industries Corp.®
- Van Air Systems®
- ElektroPhysik®
- HoldTight®
- Blast Booth, Wheel Blasters & Dust Extraction Equipment
- Containment Sheeting
- Wide range of Blasting Abrasives, Steel Grit & Shot, Aluminium Oxide, Plastic

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Jotun Australia

www.jotun.com

Stand Numbers: 44 & 45

Jotun is one of the world's leading manufacturers of paints, coatings and powder coatings with over 9600 employees with 68 companies and 33 production facilities on all continents. Jotun has agents, branch offices and distributors in more than 90 countries. Jotun Australia Pty Ltd supplies Protective, Marine, Fire Protection Coatings and Powder Coatings nationally, providing a high level of local service, manufacturing locally while supported by Jotun's global strength to provide best practice solutions. Concepts supported include Offshore Oil & Gas Production, Hydrocarbon Processing Industries (HPI), Energy, Mining, Infrastructure, Pipelines and maintenance. Marine Dry Dockings, New Builds, Tank Coatings, etc.

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Marine & Civil Maintenance

www.marineandcivil.com.au

Stand Number: 19

Marine & Civil Maintenance Pty Ltd (MCM) is an engineering rehabilitation specialist. We rejuvenate critical ageing infrastructure such as wharves, bridges, buildings and industrial facilities by re-engineering and extending the asset's life through optimised Whole of Life solutions.

Over the last 15 years MCM has built an enviable record of delivering high-quality engineered solutions in concrete repairs, cathodic protection, protective coatings, structural strengthening and other specialist activities. Embedded within our workforce, we bring this essential expertise and experience, ensuring the successful delivery of complex infrastructure assets on time and on budget.

Alan Bird, Managing Director
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Email: alanb@marineandcivil.com.au

Metal Spray Suppliers NZ

www.metal-spray.co.nz

Stand Number: 18

Metal Spray Suppliers NZ Ltd (MSS) are New Zealand's leading experts in thermal spray coatings, equipment and consumables specialising in long term corrosion protection of major assets subjected to harsh environments. Our knowledge extents to a global community of some of the worlds most experienced organizations. We have consulted on, provided coating specifications and supplied the equipment and materials for some of New Zealand's largest infrastructure and high profile engineering projects. With over 30 years in the industry and with our own in-house NACE coating inspector, MSS are totally dedicated to the continuing performance and promotion of the Thermal Spray industry.

Matt Vercoe, Technical sales & NACE Inspector
or Jacques de Reuck, Director
Phone: +64 021 322 257 or +64 021 939 580
Email: matt@metal-spray.co.nz
or jacques@metal-spray.co.nz

MRJ Industrial Services

www.mrjindustrial.com.au

Stand Number: 56

MRJ Industrial Services provide services and products in the construction industry and are a company built on over 25 year's industry experience.

MRJ have partnered with leaders in the industry bringing the latest technologies to the Australian market from many corners of the globe.

MRJ offer supply, supply and install, training (on or offsite) and full specification services to architects, engineers, asset owners and end users with service based integrity, leaning on the vast experience of our international product partners.

MRJ's technologies are spread over a wide variety of market sectors including but not limited to mining, construction, marine, civil, commercial and residential.

Phone: +61 3 6268 6027 or +61 419 348 846
Email: admin@mrjindustrial.com.au

Munters

www.munters.com.au

Stand Number: 11

Munters is a global leader in energy efficient air treatment solutions based on expertise in humidity and climate control technologies. We can deliver state of the art dehumidification equipment for short-term or long-term climate control to any location throughout Australia and New Zealand.

For over 60 years, Munters has engineered and manufactured equipment to solve humidity and climate control problems. Our technicians will install, set and monitor equipment throughout the duration of your project. Our technical expertise enables us to advise you on your optimal requirements, giving you reassurance that the job will be completed efficiently and cost-effectively.

We provide:

- Corrosion Control
- Surface Preparation & Protective Coating
- Utilities (Oil & Gas, Power Stations)

Khalid Shaikh
National Project Manager
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NACE International

www.nace.org

Stand Number: 16

NACE International, The Worldwide Corrosion Authority, serves more than 36,000 members in 130 countries and is recognized as the premier authority for corrosion control solutions. NACE International's global membership includes engineers, inspectors, technicians, scientists, business owners, CEOs, researchers, educators, students, and other corrosion professionals. Located in Houston, Texas, with offices in the U.S., China, Malaysia, Saudi Arabia, and Brazil, the organization serves all industries impacted by corrosion.

NACE International is the key resource for corrosion prevention and mitigation, technical knowledge and information, conferences and exhibitions, industry standards, reports, publications, and the most specified technical training and certification programs worldwide.

FirstService
Phone: +1-281-228-6200
Email: firstservice@nace.org

NDT EQUIPMENT SALES

www.ndt.com.au

Stand Number: 17

NDT Equipment Sales has been trading since 1992 and is a leading supplier of equipment for detecting Corrosion Under Insulation (CUI). Our extensive range of products include gamma and x-ray equipment, radioactive sources, ultrasonic equipment, hardness testers, eddy current systems, magnetic particle equipment and consumables. We are proud to be distributors for specialist CUI equipment manufacturers, including Lixi, Inc. (The Profiler™); QSA Sentinel: (OpenVision™) and NOVO (Digital Radiography). Joining us on the stand this year will be Life Sciences NZ Ltd, the local QSA Sentinel Agent.

David Morphett, NDT Equipment Sales
or Colin Meadows, Life Sciences NZ
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NMT Electrodes

www.nmtelectrodes.com

Stand Number: 43

NMT® Electrodes is a well-established name in providing high quality, cost effective solutions and products in the field of Cathodic Protection. NMT® Electrodes' Mixed Metal Oxide (MMO) and Platinised titanium Anodes are the products of choice and are used and specified worldwide for use in concrete, underground storage tanks, pipelines, offshore and marine installations among numerous other applications. NMT® Electrodes' full range of tubular, wire, ribbon, rod, mesh, mesh ribbon and plate anodes are available from its Australian and South African facilities.

Kim van Loggerenberg
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Stand Number: 23

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David Celine, Managing Director
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Email: aussales@omniflex.com

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Stand Number: 27

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Stand Number: 37

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Pipe & Infrastructure & Universal Corrosion Coatings

www.pandi.co.nz & www.unicc.com.au

Stand Number: 60

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David Oliver, PANDI or David Anderson, UCC
Phone: + 64 272 471 686 or +61 417 163 161
Email: david@pandi.co.nz or d.anderson@unicc.com.au

PPG Industries

www.ppgpmc.com

Stand Number: 35

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Gary Janmaat, Sales Manager NZ
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Rhino Linings Australasia

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Exhibition Stand: 52

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Russell Fraser Sales

www.rfsales.com.au

Stand Number: 29

RFS NDT

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For the corrosion mitigation industry, RFS supplies Creaform 3D Laser Scanners for pipeline integrity assessment, Ultrasonic Thickness Gauges, Ultrasonic Phased Array, Holiday Detectors, Thermal Imagers, Borescopes, Field Microscopes, Surface Replication products and more.

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Rust-Oleum Industrial Brands

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Stand Number: 62

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Savcor Products Australia
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Stand Number: 10

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Vinay Swaroop
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Sika NZ
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Stand Number: 34

Concrete corrosion tamed for up to 50 years!

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Sika is a global leader in concrete repair, strengthening and technology. Sika's new Ferrogard Galvanic and Hybrid Anode technologies can deliver up to 50 years concrete corrosion protection without the need for monitoring or maintenance! See the Sika Ferrogard display at the Conference.

Reuben Reeves,
Refurbishment & Strengthening Manager
Phone: +64 275 617 751
Email: reeves.reuben@nz.sika.com

Sulco
www.sulco.co.nz

Stand Number: 12

Sulco Ltd. is a privately owned NZ Company with a long history in the Pipeline Industry in NZ. Today Sulco offers a wide range of products. Including Polyken, Covalence Shrink Sleeves, Powercrete and Anodeflex. All products for the protection of steel pipes in ground come from Berry Plastics USA. In addition Sulco represents Spy Holiday Detectors USA and Girrard USA makers of pipeline pigs. Sulco has experienced sales staff ready to answer your enquires and to provide competitive pricing. The tool division of Sulco stocks a wide range of pipe working tools and are the exclusive agents in NZ for Knipex Germany.
For further details phone toll free 0800 800 488 or email sales@sulco.co.nz.

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SVENIC
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Stand Number: 04

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Svenic also provides filling, labelling, and assembly of two part cartridges, syringes, and other containers filled with sealants, adhesives, coatings and foams.

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- Advise, testing and package suitability
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Peter Coundouris
Phone: +61 7 5539 2255
Email: peter@svenic.com.au

Syntech – Surface Finishing Specialists

www.syntechnz.com

Stand Numbers: 39, 40 & 41

Syntech – surface Finishing Specialists has been supporting and supplying the Corrosion and Protective coating industry for over 26 years.

Syntech provides both Equipment and consumables to treat corrosion and other surface anomalies in the following areas of expertise.

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William Bettle, Sales Manager
Phone: +61 9 820 2121
Email: sales@syntechnz.com

TBS Group

www.tbsgroup.co.nz

Stand Number: 15

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TBS' core service offering includes; industrial coatings, transmission tower maintenance, industrial waterblasting, wind farm maintenance, commercial building services, asbestos removal, building and structure remediation, refractory installation and maintenance and scaffolding, rigging and access.

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Wattyl Protective Coatings

www.wattylpc.com

Stand Number: 38

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Jasmine Moey, Marketing Manager
Phone: (AUS) 132 101 or +61 4093 660 01
Email: Wattylprotectivecoatings@valspar.com

W A Stroud Ltd

www.strouds.co.nz

Stand Number: 01

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Matthew Berry
Phone: +64 275 673 049
Email: matthew@strouds.co.nz

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EcoQuip® 2 Makes any job easier, compare for yourself

- EcoQuip 2 is designed to accept any media heavier than water and has a blast rating of up to 175 psi.
- The versatility of EcoQuip 2 is one of the characteristics that makes this equipment so remarkable. The best part is how easy it is to switch from one application to another.
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Applications:

- Concrete repair, coating removal, steel surface preparation and graffiti removal.

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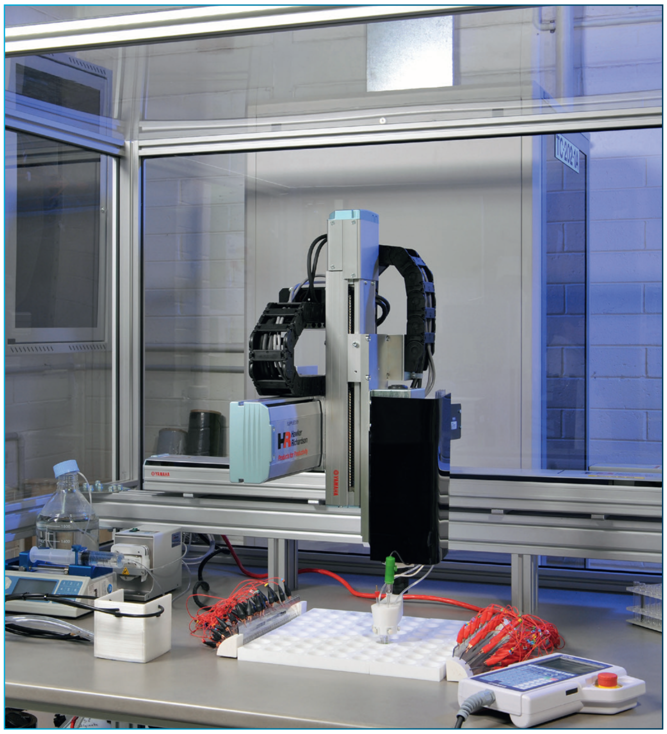
High Performance Metals

CSIRO's High Performance Metal Industries (HPMI) Program is developing next generation technologies for the production of metals and surface coatings that will shape the future of industrial manufacturing. Our aim is to help organisations capture opportunities in the face of a changing manufacturing industry, through innovative sustainable processes and high performance alloys, coatings and technology solutions.

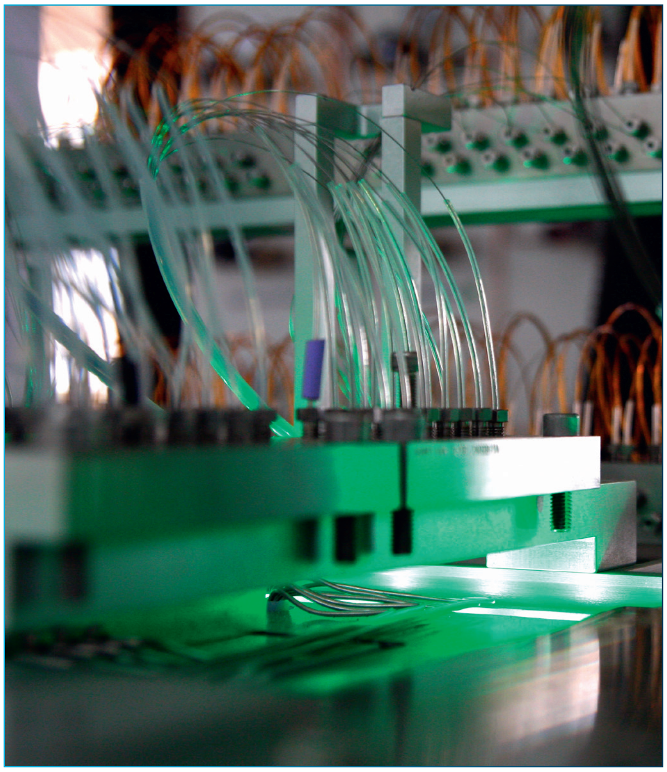
The program's core capability is in the design and production of metal and coating systems that govern the properties of both passive and active materials, combining the latest computational methods with traditional and additive manufacturing methodologies. Through our Lab 22 initiative, we are advancing 3D printing of a range of titanium, steel, and novel alloys that can offer high efficiency and productivity gains for a competitive advantage. By coupling our advanced modelling and simulation capabilities with novel metal production techniques, we are contributing to the renewal of traditional metal production and manufacturing industries using design, process control, cost reduction methods and modelling and simulation. These are all underpinned by our strong capability in hard and soft coatings technologies, which offer significant lifetime enhancement, corrosion protection and an ability for embedded sensing of local environments, particularly applied for the protection of infrastructure.

High throughput discovery of inhibitors

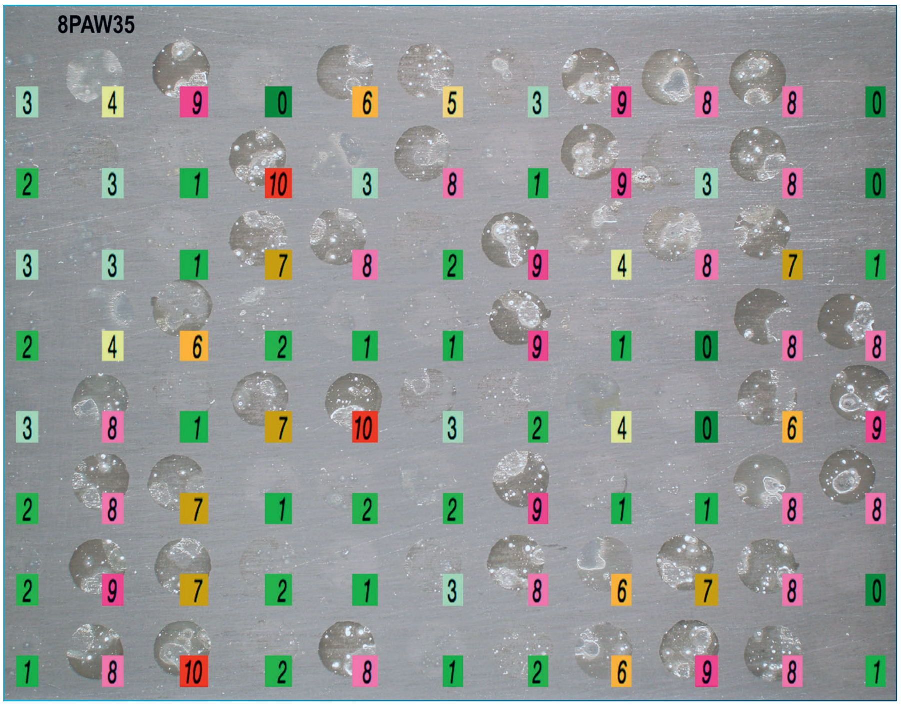
Current inhibitor technologies, particularly those based on chromate, are extremely toxic, both to human health and the wider environment as a bio-accumulator. Inhibitive coatings are undergoing significant advances driven by the need to reduce toxicity whilst improving functionality, such as self-healing mechanisms. With few commercially viable alternatives to chromate, the race is on to meet this tremendous need for environmentally friendly corrosion protection systems. CSIRO is at the forefront of these new developments. We have developed a new high throughput methodology which can enable the rapid screening of new formulations of organic and environmentally friendly materials as the next generation of corrosion inhibitors. Using our high throughput techniques, we have scanned thousands of inhibitors in a range of aggressive test conditions. High throughput testing allows us to find previously undiscovered synergies between different inhibitors and surfaces thus enhancing performance.



The FASTER robot can perform repetitive tasks 10 times faster than humans. Credit: CSIRO



High throughput discovery of inhibitors: Credit: CSIRO



88 simultaneous different corrosion inhibitor tests on aerospace aluminium in 24 hrs. The colour coded scale uses an optical method to rank the corrosion inhibition from 0 (green, excellent inhibition) to 10 (red, poor inhibition). Credit: CSIRO

CSIRO's High Performance Metals group are working towards enabling the commercial manufacture of new alloys with superior properties. Credit: CSIRO

Robotic electrochemistry and computational design

A major issue faced by several industries, in particular the aerospace industry, is the mismatch between materials research, development and qualification cycles and the design and manufacturing cycles of modern aircraft. Typically, for every material qualification, two new series of aircraft can be designed and prototyped, meaning next generation materials won't fly on next generation aircraft. To combat this fundamental misalignment, CSIRO has developed two complementary technologies to reduce labour and accelerate the time taken to develop and qualify new materials systems and anti-corrosion coatings. The first technology, FASTER is a rapid electrochemical screening test which leverages robotic experimentation and provides automatic results analysis to yield a throughput which is around 10 times faster than traditional lab based studies by running experiments round the clock. The second technology, known as computational design, allows molecular level design of materials, as well as simulation of lifetime performance given a set service conditions i.e. temperature, local contaminants, salt loadings, etc. Together, FASTER and computational design form a formidable framework for accelerating the R&D cycle of novel materials and coatings.

New alloys

The challenge with current aluminium (Al) alloy welds is that they are weaker than base materials, with thermal expansion and solidification shrinkage often leading to cracking. Micro-cracks can in combination with fatigue loading lead to premature failure and corrosion. In many cases, much thicker Al alloy plates have to be used to overcome the weak weld problem, resulting in excessive weight increase.

CSIRO has developed a new weldable, high-strength Al alloy that allows seamless joins between panels, minimising defects that may act as corrosion sites while maintaining high strength and ductility. The new alloy is enhanced by advanced solidification and nano-scale alloying technologies with minimised segregation and optimised microstructure. It has high weld yield strength in the range of 300-400MPa compared with standard 5083 welds down to 120-140MPa while maintaining high elongation of 20-25 per cent. With superior mechanical properties, this alloy has many applications where lightweight and corrosion resistance are critical, such as aircraft and marine vessel manufacture.

Solutions for your business

We're ready to partner with companies and research organisations to develop and apply new innovative technologies to enhance your products. We foresee many, diverse opportunities for future growth for Australian manufacturers. Our science-based innovations can help boost commercial opportunities and increase profits.

We form partnerships in a variety of flexible ways, including through research partnerships, researcher placements, consultancy services and commercialisation of our IP. For more information on our work with industry and how to engage with us, visit: **www.csiro.au/metals or contact Rod Thomas on 03 9545 2250.**

CSIRO

Hybrid Cathodic Protection Systems Save a New Zealand Bridge

Corrie Cook

For the first time in New Zealand a local operator has provided a state of the art hybrid corrosion protection system on concrete support piles under a major highway bridge in Auckland. This technology was designed by international experts whose research has revolutionised the understanding of how impressed current cathodic protection (ICCP) performs.

This paper is a summary of the new technology being used to extend the life of bridges on the State Highway 16 Causeway Project near Auckland. The technology is built on work discussed at C&P15 in Adelaide last year and follows the paper on the first use of Hybrid CP presented to C&P 13 in Brisbane in 2013.

The hybrid anode system combines elements of re-alkalisation, cathodic protection and galvanic protection which can be applied as a global or a targeted protection system for the concrete element or the whole structure.

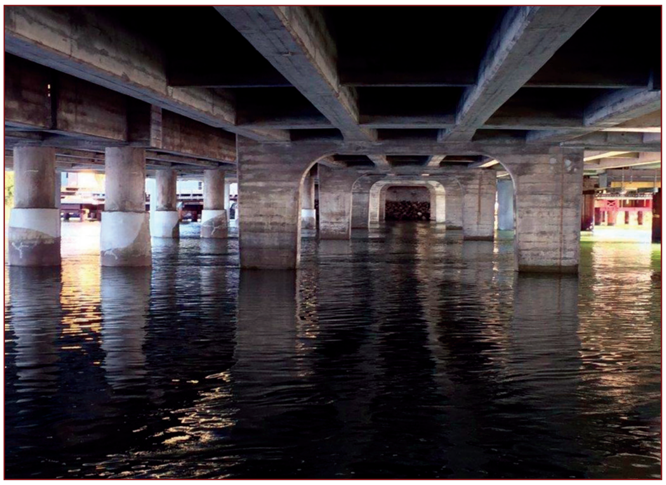
Background

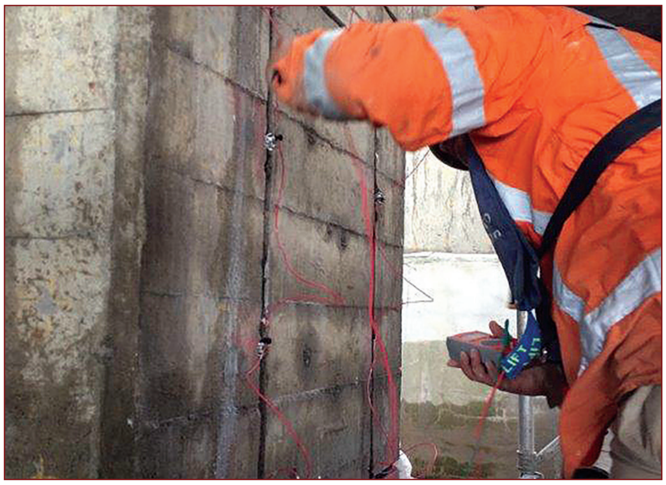
In the UK and Australia, investigations have been conducted into the occasional positive effects of interrupting cathodic protection on reinforced concrete structures. Preliminary laboratory results suggested that applying ICCP to a reinforced concrete structure over a period of time can transform the environment around the reinforcement, even after the protective current had been interrupted.

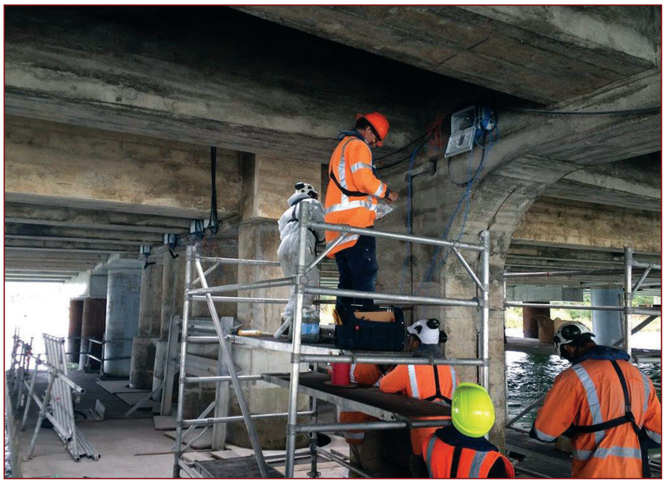
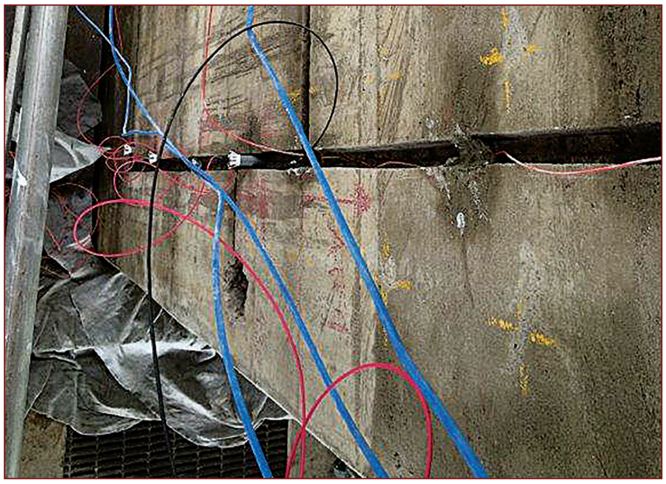
In his presentation Dr Christian Christodoulou, a Technical Director with AECOM Ltd in the UK, whose expertise covers the field of corrosion asset management, repair and refurbishment of concrete structures, noted that, “ICCP has been the most popular electrochemical solution for the repair and maintenance of reinforced concrete structures worldwide. It can arrest corrosion activity and extend service life in a very sustainable manner, by reducing the need to remove chloride from salt-contaminated but otherwise sound concrete.”

Applying cathodic protection to a reinforced concrete structure is accepted as a cost effective way to transform the environment around the reinforcement, and move it from being aggressive to passive. This transition is achieved by chloride ion removal and increased alkalinisation through the reduction of interstitial water and dissolved oxygen. Under these changed conditions, the microenvironment is benign and so corrosion ceases.

The key finding of their research was that, in the event of the impressed current system being interrupted for long periods, the steel remained passive for at least 52 months, even in the presence of chloride ions, on highway structures in the UK and Australia. Even in the more aggressive environments associated with marine structures, it was shown that in the majority of cases examined, steel potentials moved towards more positive values that suggest passive conditions were maintained.





The hybrid system in NZ

Repairing marine structures is especially problematic when they have been made of reinforced concrete. This is due to a combination of heavy wear and abrasion from wave action and inter-tidal saturation with salt water means that chloride-induced corrosion can advance very quickly.

Sika (NZ) Ltd is working with Dr Christodoulou to ensure that the proposed hybrid anode system will work effectively on the Auckland bridge. Some of the original piles were installed over 40 years ago, and appear to have lasted well according to assessments by members of the local Sika team.

Utilising corrosion potential mapping, the overall environmental condition of the piles within the concrete proved to be successful. This mapping was conducted at the concrete's surface with either a silver/silver chloride or copper/copper sulphate half-cell, in electrical connection to the existing reinforcing.

Following installation of the relevant reference electrodes on a predetermined grid design, a series of titanium-manganese dioxide anodes were installed. This allowed the designer to measure the effectiveness of both the impressed current and cathodic protection systems, using readings taken from inside the pile structure. These readings were collected via a data-logger and the results were relayed to the designer, which facilitated the optimal placement of the hybrid anodes.

Following confirmation of this plan the anodes were then installed in drilled holes and connected via titanium wire. The advantage of such installations is that in each location the designer has the ability to adjust the amount of current to selected zones, depending on whether the area is predominantly a tidal, splash, or atmospheric zone. Once a suitable current has been passed in this impressed current phase and the zone is appropriately passivated, the power supply can be removed from the appropriately passivated zone and a galvanic phase of protection is initiated.

Traditionally the options available to asset owners for chloride or carbon-dioxide contaminated concrete have included:

- Breaking out and replacing all of the contaminated concrete, which is a cost prohibitive exercise.
- Application of a surface applied corrosion inhibitor (SACI) - with a short term (10 years) life span and limited penetration with chloride rich concrete environments.
- Re-alkalisation or chloride extraction - can be difficult to achieve success and to effectively monitor.
- Impressed current cathodic protection – drawbacks with on-going costs of monitoring, control, power supply and cable maintenance

Patch repairs

In the case of marine structures, steel is typically de-passivated by chlorides migrating through the concrete from the external environment, building up in sufficient concentrations at the steel-concrete interface to damage the naturally protective iron oxide film.

Once de-passivated, iron oxides and hydroxides develop at the anode as a result of oxidative hydrolysis of the primary corrosion products. The resulting massive volume expansion provides the driving force for the spalling of the concrete cover on the steel reinforcing bars, exacerbating the corrosion problem.

Concrete patch repair is a common technique for this challenge, involving the removal of physically deteriorated concrete, cleaning the steel reinforcement and replacing with a repair mortar. However, in many cases further corrosion is soon observed around concrete patch repairs. This phenomenon is usually known as incipient or ring anode formation.

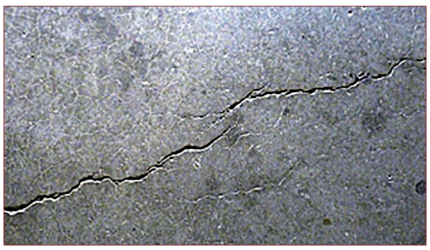

Concrete Problems Today are Multifactorial - Root Causes

by Hamid Khan, Brand Manager - Concrete Durability | Parchem Construction Supplies Pty Ltd

Regular and planned asset maintenance is vital for reinforced concrete structures. Such maintenance should not be a 'cosmetic repair' but rather a proper root cause analysis that must be carried out to identify and understand the actual source of the problem. Material selection is an important step in asset maintenance and refurbishment projects though only after the root cause has been addressed. Conducting proper root cause analysis in restoration and refurbishment projects will prevent one from falling into a vicious cycle of 'repairing the repair'. A study conducted by Jingmond and Ågren (2015) has highlighted the importance to look at the root causes of the defects in concrete from the organisational perspective as well, instead of only at the operational level.

A defect or problem in an existing reinforced concrete structure is multifactorial; it often stems from obscure reasons. Like the cause of a common headache that is often attributed to a pathological cause leading to expensive and often needless investigations and treatments, whereas, the actual cause may be a stress-triggered tension headache. Similarly, stomach infections are common during monsoons in Asia, which are due to the 100 year old corroded sewage pipes leaking into the parallel running municipal water pipes. A point to ponder here is whether treating the gastro patients with medicine or changing water filters would make the situation better without addressing the root cause of the problem?

Corrosion of steel generates iron oxides and hydroxides, resulting in the increase of volume 5 to 8 times of its original size. This increase in volume causes expansive forces to accumulate within the concrete around reinforcement and results in cracking and in areas with low cover, concrete spalling. Cracks provide easier access to oxygen, moisture, chlorides and other corrosive agents that create conditions suitable for accelerating the electrochemical corrosion process. Pretensioned concrete bridge girders may exhibit unexpected end cracking upon pre-stress release. These cracks may propagate into the bottom flange of the girder where strands are located and can increase in width with increased traffic loads. Leakage from the bridge expansion joint could penetrate the bottom flange cracks and trigger severe corrosion. In this case expansion joint leakage must be arrested prior to the crack and concrete repair activity.



Concrete Cracks provide easy access to corrosive agents.

A common form of cracking at an early age on new concrete decks is known as *transverse cracking* which may appear over the length of span above transverse reinforcement. These cracks can accelerate corrosion rates, reduce the service life of the asset and increase maintenance costs. When a mass of concrete that shrinks as it ages is restrained, cracks will occur. For example, restraint of a concrete deck by an integral support girder against its volume change initiates cracking. Multiple factors such as concrete materials and mix design, ambient temperature changes, humidity, bridge design characteristics and construction practices can all contribute to volume change and/or to degree of restraint of concrete mass. However transverse cracking cannot be attributed to all of the above factors. It is therefore important to identify the major contributing factor(s) to address the root cause of cracking.

Linear Transverse cracks on new bridge deck due to plastic shrinkage.

Surface grinding to open the face of the crack and sealing with epoxy resin.

A crude approach while examining the corrosion induced damage in bridge structures, particularly in the marine environment, is to assume the presence of chlorides as the main cause of failure. Chlorides might be the reason of corrosion but not the actual cause of the bridge defect. The root cause of failure of the bridge structure cannot be simply corrosion. There are many factors involved that could lead to corrosion and ultimately lead to failure of the bridge, such as, cracks in bridge girder web and flange, poor bridge drainage system, failed bridge deck waterproofing membrane, inappropriate bridge joints, void in the prestressed or post tensioned cable ducts due to excessive grout bleed. Other factors at macro level are related to design, material, environment and construction practices. It is important to address the main contributing factor(s) of the defects in bridge structures affected by corrosion.

It is quite common to observe local white patch of efflorescence that appears like a chalky powder at ground floors due to rising or penetrating dampness inside institutional buildings, hotels and residential apartment buildings. This phenomenon occurs due to number of factors. For example, one of the factors is the absence of or damage to the damp proof course which allows entry of moisture from the ground below, or from unsealed landscape planters outside hotel rooms, which seep through the external walls and result in white patches of dampness along the perimeter of the internal wall. Treating the damp patch from inside would only solve the problem temporarily as it could recur unless the damp proof course is repaired.

Cathodic protection to bridge piers affected by cracks, corrosion and spalled concrete, using embedded galvanic anode units (top) and distributed galvanic anode system (bottom).

Concrete repairs conducted without considering the actual source are 'cosmetic repairs' and may last only for few months. For instance, repairing the spalled concrete of a balcony with quick-fix patch method, even applying the best quality repair mortar, would not solve the problem unless the root cause has been identified and addressed. It could be attributed to more than one cause such as leakage due to failure of waterproofing membrane, a broken drain pipe, leaking concealed pipe joints or a combination of these factors. Corrosion of reinforcement that has caused spalling of balcony is not the root cause here.

Repair of balcony concrete corrosion and spalling due to multiple factors.

Roof leakages in buildings result in seepage into the rooms below. This causes discomfort to the occupants and frequent disputes between the landlord and the tenant in regard to the liability for repair. The failure of roof waterproofing is often attributed to the poor workmanship. Based on this notion, the roof refurbishment is carried out but the leaks appear again after some period of time. Research conducted by Lo, Leung and Cui (2005), on roof construction defects have highlighted that the root cause of failure of the roof waterproofing membrane stems from the roof parapet wall cracks. It further concluded that the design and choice of material for a roof parapet wall is critical to avoid waterproofing membrane failures on the roof slab. Other reasons for roof leakage could be wrong termination details of the waterproofing membrane at up-stands and drains, improper selection of the waterproofing system and poor roof joint detailing.

Soffits severely corroded due to roof leakage into a residential building.

External tiles falling from the building façades can cause damage to assets and pose a potential safety hazard to pedestrians. The number of casualties and injuries caused by the failures of external wall finishes is a serious concern to the authorities in many countries. Ho, Lo and Yiu (2005), in their research highlighted various factors that could lead to external tile failures such as thermal and moisture effects that induce movement of tiles, inferior quality adhesive, poor workmanship, improper joints, weathering, vibration and substrate properties. The failure could be due to a single factor or it could be the effect of a combination of the above factors. It is therefore vital to recognise and address all the major contributing factors of the de-bonding and falling of tiles.

Finding the real cause of a concrete problem rather than merely dealing with its symptoms is the key to success for a durable repair and refurbishment project. Aspirin quick-fix approach in handling concrete defects may only provide a temporary cosmetic solution. The aim of this article is to create an awareness among the civil contractors and engineers that to solve the concrete defects effectively, they need to drill down through the symptoms to establish the actual root cause. Re-examining, re-designing, re-assessing, re-selecting, re-applying and lots of 're-s', can easily be avoided by examining and fixing the *root cause* of the concrete defect to ensure the same problems are not recurring.

Geraldton Concrete Silos Remediation:

A Case Study in The Structural Strengthening and Concrete Repair Practices Utilised for the Ongoing Operational Efficiency and Durability of Concrete Silos

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Freyssinet Australia Pty Ltd

Project Overview

The CBH Group is one of Australia's leading grain organisations, a co-operative with operations including grain storage, handling and transport, to marketing shipping and processing, based in Western Australia. It has been established for 80 years and is owned and controlled by more than 4500 grain growers.

The CBH Geraldton base is located in the north of the state's growing region and consists of receival and administration facilities, along with port terminals for export. As part of this receival facility, Geraldton has twenty four (24No) reinforced concrete grain silos which were constructed from slip formed concrete in the mid 1960's. These silos were constructed as circular grouped silos in a bank of 8 x 3 No. interconnected/adjoining silos, each 36m in height and 13m in diameter, resulting in a plan layout of 100 metres long and approximately 40 metres wide. This layout formed internal star cells between the main silos which are used to store boutique grain. The walls of the silos are around 200mm thick and the wall reinforcement consists only of a centrally placed single mat.

In more recent years evidence of extensive vertical cracking was noted throughout the walls of these silos and this lead to various investigations and structural assessments. As is typically found for circular grain storage facilities of this type and age, it was concluded that the original design understanding was inadequate to cater for the peak loads occurring during grain outflow. The resulting structural cracking reflected this structural inadequacy, and given the marine environment in which the silos are located, also raised concern in regard to the long term durability of this structure.

Insufficient hoop reinforcement in the silo walls had resulted in extensive vertical cracking and led to restriction in grain loading and operation. As the silos are also located in a temperate marine location, 40 years of chloride ingress had also led to significant corrosion to the embedded reinforcement resulting in widespread delamination and spalling.

Project Summary

Following on from failed attempts at remediation during the early 2000's by others, Freyssinet were invited to put forward solutions for strengthening and remediation as a result of successful completion of numerous similar projects throughout Europe and the Middle East. This approach was largely one of providing a complete design and construct solution.

Previous structural assessment reports were assessed, and further grain testing and load modelling was undertaken by recognised specialist organisations. Freyssinet then completed a full in-house structural design for strengthening which included sophisticated finite element analysis and design to current Australian Standards. In addition to this, a durability assessment was undertaken by concrete sampling as well as a corrosion survey using half-cell potential mapping. Solutions for long term repair and protection were based on the results from these investigations.

The original 1960's design allowed for only static loading to the structures and failed to account for the 'funnel' effect during the emptying of the silos with insufficient hoop reinforcement in place to deal with such live loads. The most common design errors were bending of circular walls caused by eccentric withdrawal, large non-symmetric pressure caused from inserts, ignoring flow patterns and materials properties concerning temperature and moisture, corrosion of steel reinforcing bars in the concrete and improper reinforcement.

Forty years later their condition had declined to an extreme state rendering them in need of extensive structural strengthening and specialist concrete repair works which included ultra-high pressure hydro demolition and dry process gunite reinstatement.

Leading on from these investigations and designs, Freyssinet were engaged to carry out initial prototype repairs and strengthening to an initial three silos in order to verify and refine work methods and scope for the remainder of the structure. These works were undertaken from a series of special purpose mast climbers which provided for access platforms contoured to the silo geometry. Repairs were undertaken using techniques commonly used throughout the Freyssinet group internationally, including a combination of hydro-demolition and dry process shotcrete. Staging of the repairs was originally not anticipated, but was found to be necessary given the very large scale of these works, with this structural assessment undertaken internally by Freyssinet.

Structural strengthening was undertaken using proprietary Freyssinet external post tensioning including 1R15 anchorages, with successful completion of these initial works confirming the design assumptions. The prototype was completed over a twelve month period. Based on the extensive learning and verification made possible during this initial prototype, along with the inclusion of certain methods preferred by the client, the scope of ongoing work was refined and re-valued.

In order to verify the Freyssinet techniques for repair and strengthening initial works included the construction of a prototype off site to confirm the accuracy of coring of the interconnecting diaphragm between silos as shown in Figure 1.

Figure 1 – Construction of prototype.

Figure 2 – Cored tendon placement holes.

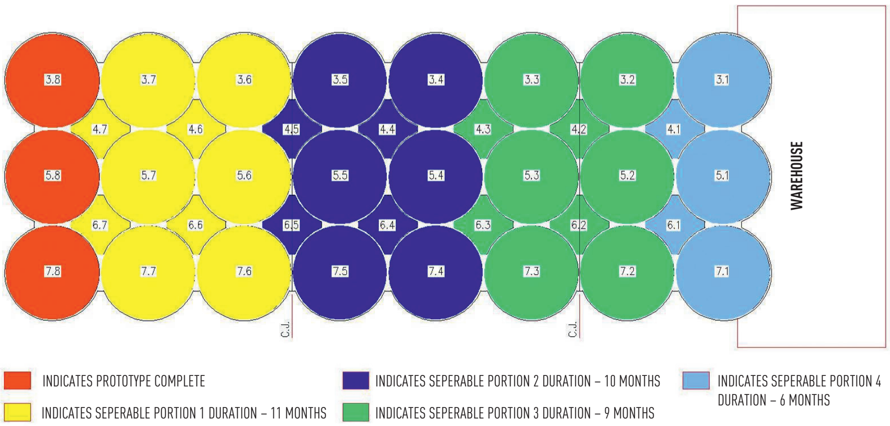

Figure 3 – Breakup of each phase of works.

Figure 5 – After Kevlar tape removal from side of Silo 7.8.

Coring of primary 90mm diameter holes through the 4500mm long diaphragms was completed with secondary core holes drilled to intercept these, allowing tendons to pass around the full circumference of each circular cell as shown in Figure 2.

Works on site commenced in 2008 on the first three silos as part of the initial 18 month 'prototype' phase. This phase was then followed by the 'full scale works' whereby the overall works package was split into four distinct separable portions (SP1 – SP4) with each addressed as sequential independent schemes as illustrated in Figure 3.

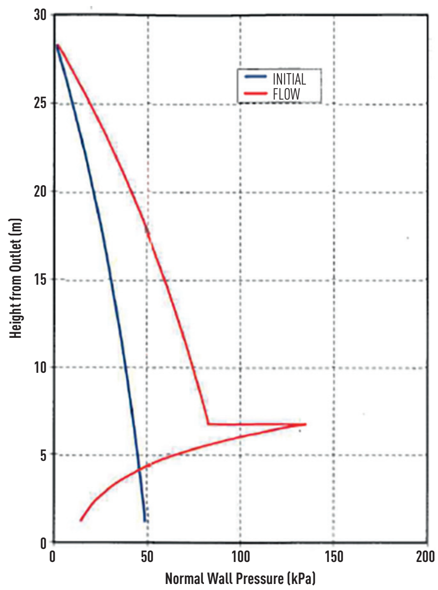

Figure 4 – 'funnel' effect on wall pressure.

Understanding the Problem

Initial site inspections gave a clear indication of the level of cracking on the silos. Extensive areas were visible where corrosion was evident due to delamination of the concrete and pimples/lateral deformations on some silo walls, as a result of the 'funnel effect' (Figure 4) during the operational use of the silos.

Some remediation works had been carried out previously on the cracking with Kevlar tape placed over each crack to try and stem the cracking and also seal the cracks from the elements. The extent of the cracking exposed can be clearly seen in Figure 5 following removal of the tape as part of the initial repair process.

A corrosion survey was undertaken by potential mapping using half-cell testing equipment as shown in Figure 6.

After detailed hammer surveys, coupled with exploratory breakout 'windows', areas of concern were identified, catalogued and each silo mapped accordingly which allowed for a repair scheme to be formulated in what became known as the 'prototype' phase of the works. The 'prototype' phase of the works utilised separate twin profiled mast climber systems for access to carry out the surveys and the repair works as shown in Figure 7.

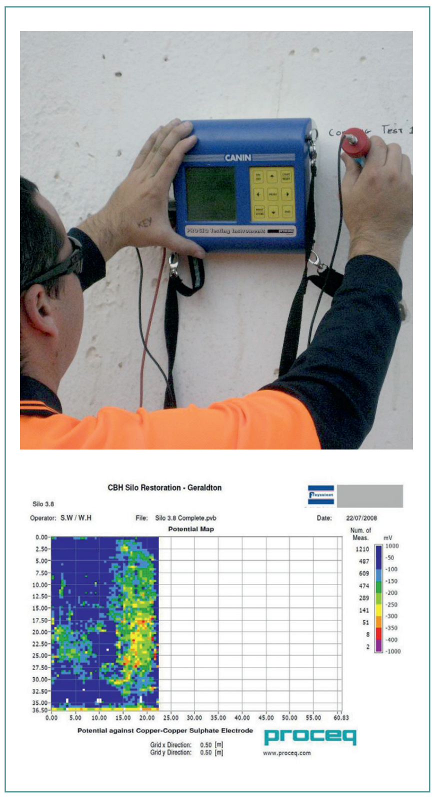

Figure 6 – Potential mapping by half-cell testing.

Figure 7 – 'Prototype' phase profiled mast climber system.

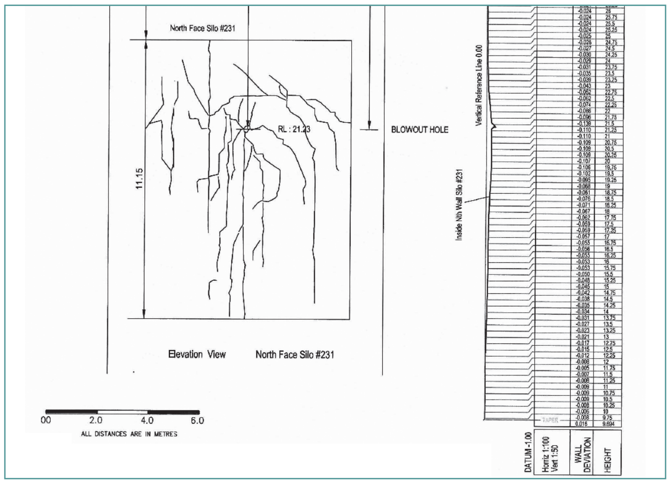

Figure 8 – 3D mapping showing lateral bulge in Silo 3.1 wall structure.

Internal 3D scanning of the worst affected silo (3.1) was carried out noting the 'full thickness' cracking that was affecting this particular silo wall. These cracks coincided with areas of the wall that appeared to be 'bulging' outwards (as shown from the 3D mapping in Figure 8). The 3D scanning mapped the extent of the internal cracking and also the profile of the lateral deformation in the wall. For this case a methodology for a full depth repair was required and developed.

These initial trials led to development of a structural repair and strengthening solution comprising of the Freyssinet 1X15 external post tensioning system being utilised as the structural strengthening component to combat the insufficient hoop reinforcement, together with varying different concrete repairs techniques to combat the extensive cracking, delaminated concrete and lateral deformation affecting one of the silo structures. Due to the facilities proximity to the coast the cracking also contributed to widespread chloride induced corrosion of the existing reinforcement embedded within the structure.

Repair Solutions

After the 'prototype' phase, Freyssinet Australia was engaged on a full design and construct contract to remediate the remaining 21 interconnected silos and the 14 star cells. Execution of the rehabilitation solution involving various different concrete repair techniques and structural strengthening, discussed in detail hereafter, which ensured the ongoing operational efficiency and durability of the concrete storage facility.

The original contract estimate for repair area was set at 3000m². However over the course of the project with better access to carry out detailed surveys the final repair area grew to over 4400m². The Table 1 below illustrates the comparative spread of repair area across each of the Separable portions.

Separable Portion	Repair Quantity (m²)
SP1	763
SP2	1065
SP3	930
SP4	1680
TOTAL	4438

Table 1 – Comparative repair areas across each Separable Portion.

Out of the 'prototype' phase of the works a defined project scope of works and access requirements were developed for each silo's remediation.

Access Systems

During the 'prototype' phase of the works profiled mast climbers (Figure 7) were utilised to access the repair areas. However it quickly became apparent that this access system was not the best solution for a project of this magnitude. With such large areas of repair to be completed, the mast climber system didn't allow for

Figure 9 – Typical scaffold access on site (prior to encapsulation).

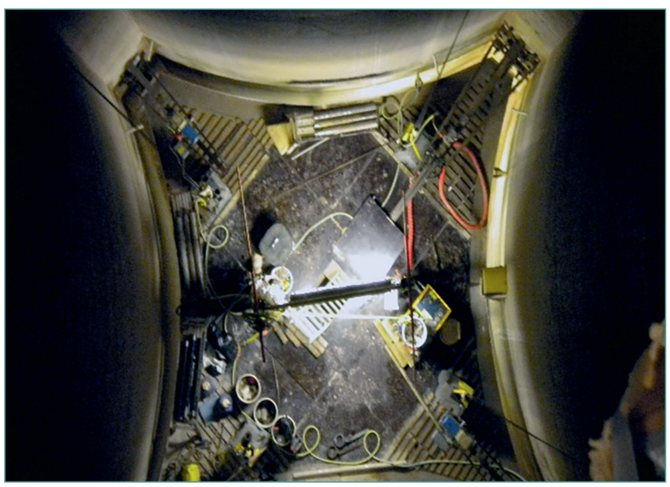

Figure 10 – Star cell scaffold platform.

the autonomy required to work on multiple work fronts at any given time. Also because of the lower safe working load (S.W.L) of the mast climbers a traditional scaffold access system (Figure 9) was utilised for SP1 – SP4.

Another unique challenge was the access system for the internal star cells. Access into these areas was a difficult challenge due to the confined space nature of the works. Access doors at the base of each cell allowed for scaffold material to be passed into each cell and a scaffold 'donut' platform (Figure 10) to be constructed to suit the cells configuration. Side guides/ rollers and a winch system was used to traverse the 'donut' up and down the star cell walls. Emergency access was by means of rope access system in/out of the escape hatch at the top of each cell created by removal of each silos grain feed chutes.

Outline Scope of Works

The following repair sequence was utilised across all silos:

1. Conduct a Hammer Survey to identify areas of defective/ delaminated concrete.

2. Remove defective/ delaminated concrete using a combination of both hydro-demolition and hand breakout techniques, and trim original concrete to give access behind (by a 'gloved hand'/ ≥25mm) the existing reinforcement.

3. Remove existing horizontal reinforcement and replace with new galvanized steel.

4. Blast and treat the existing vertical steel with a zinc-rich epoxy primer (*Nitoprime Zincrich*) to protect the steel reinforcement within the repair areas.

5. Apply concrete repairs to areas requiring reinstatement using a high strength (45 MPa), high strength, low shrinkage dry-spray gunite (*Guncrete E*) repair application (>600m³).

6. Carry out crack repairs to any remaining structural cracks.

7. Apply a 3-coat high performance water based protective façade coating system to the silo external surfaces (*EmerClad*).

8. Install an external post tensioning system using diaphragm cored holes to pass each cables external ducting which house the greased and sheathed 15.7mm strand through and around each silo at a pre-determined location (>26kN strand). Stainless steel pins were used to support the tendons. Figure 11 shows a typical tendon layout for the silo structural strengthening.

9. Reinstate all infrastructure for each silo – fumigation pipes, chutes, access towers etc.

In addition to the silos, the internal 'Star Cells' which made up the voids between the interconnecting silos and were also used for grain storage, required some works as part of the overall remediation project. The following repair sequence was utilised across all star cells:

1. Install stressing anchor to receive the external post tensioning cable.

2. Following completion of the post tensioning works, anchor steel mesh to face of each Star Cell wall.

3. Apply 80mm thick strengthening skin of wet-spray shotcrete (*Guncrete E*) onto steel mesh and finish smooth.

4. Reinstate all infrastructure for each cell – fumigation pipes, chutes etc.

Silo 3.1 required special attention in the overall repair scheme due to the lateral deformation in its mid-section as identified by the 3D mapping and also from the visible penetration through the silo wall. Once access was established, a full depth repair to an area approximately 30m2 was required. Briefed with the 3D mapping information and as-built drawings, a structural finite element analysis (FEA) was carried out to ascertain the structural integrity of the Silo 3.1 and the extent of the necessary repairs.

The results of the FEA confirmed that the silo could still function even with the lateral deformation/ 'bulge' left in place. This FEA analysis outcome allowed for the minimum possible area of full depth concrete repair to be addressed.

The results of the accompanying site investigations also highlighted the need for the extensive cracking around the full depth repair area to be treated so that the substrate would act in a homogenous manner during the stressing works, along with the need for stainless steel dowel pins to be installed to the segmented 'blocks' of concrete which had been created by the cracking.

Conclusions

The concrete remediation techniques and practices adopted on the Geraldton Grain Silos project were both varied and challenging making it a unique project within the Concrete Engineering field. The large-scale application of dry spray gunite, wet spray shotcrete, reinforcement treatment and

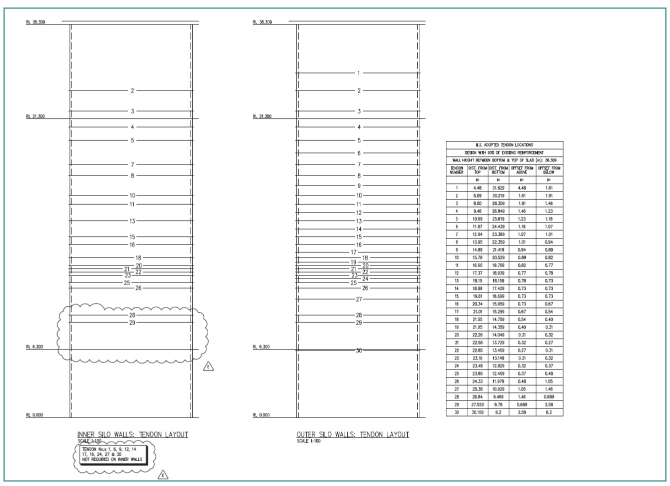

Figure 11 – Tendon layout.

Figure 12 – Project at completion.

replacement, waterproof substrate coating and external post-tensioning to the silo structures, required dedicated expertise across and range of engineering disciplines.

The successful execution of these works was also greatly reliant upon the collaborative approach adopted by both the asset owner and contractor. Without this forward thinking approach, solutions to additional problems such as Silo 3.1's full depth repair may not have been so readily derived and successfully implemented.

Moreover, the use of a prototype phase in order to establish the correct application techniques and quality management, helped contribute towards a 'right first time' culture that lasted the duration of the repair works, whilst enabling the facility to remain operational.

Not only did execution of the project allow CBH's grain terminal operations to continue without significant loss in capacity, but the overall finished product is set to provide the structure with a further 40 years of serviceable life.

The completed project value was $26M.

Key Subcontractors and Suppliers

- Hydro Demolition: UHP Solutions
- Concrete Coring: Diacore
- Surveying: Hile Thompson & Delfos
- Concrete Hand Breakout: DIAB Engineering
- Concrete Repair Materials: Parchem Construction Supplies

Project Awards

- Concrete Institute of Australia (CIA) – Industry Excellence Award in 2014 - 'My Concrete Rules Repair Category'
- Australasian Concrete Repair Association (ACRA) – Award for Excellence in 2014 – 'Mega Projects over $10m – Geraldton Grain Silo Remediation'
- ACRA – Award for Excellence in 2014 – 'Repair Industry Excellence Award – Geraldton Grain Silo Remediation'

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Author Details

John Barry is the WA Construction Manager with Freyssinet Australia.

Stuart Robertson was the Project Manager directly involved and responsible for the delivery of phase 3 & 4 of the Geraldton Concrete Silo project over a period of 18 months. .

Anthony Mesic was the WA Remedial Manager from June 2012 to April 2014 when stages 3 & 4 were being completed on the Geraldton Concrete Repair Project. Anthony was directly involved in overseeing the projects delivery, establishing the full depth repair techniques and troubleshooting new construction requirements throughout the life-cycle of the repair project.

Experiences with the Design of Repair and Protection Measures for Concrete Structures

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Introduction

Concrete is a wonderfully versatile construction material. When reinforced with steel it enables the design and construction of a plethora of buildings, bridges, tunnels, wharves, jetties, mining structures, offshore structures and industrial plants. When suitably designed, constructed and maintained, reinforced concrete provides an extended service life to such structures and buildings. The material properties of concrete provide embedded reinforcing steel with excellent corrosion protection. The highly alkaline environment in concrete results in the formation of a stable, tightly adhering, passive oxide film on reinforcing steel, which protects it from corrosion. In addition, well proportioned, compacted and cured concrete has a low penetrability, thereby minimising the ingress of corrosion-inducing species via the aqueous phase, and a relatively high electrical resistivity, which reduces the corrosion current and hence the rate of corrosion if corrosion is initiated.

There are however, several degradative processes which affect some reinforced concrete structures and buildings leading to loss of functionality, unplanned maintenance/remediation/replacement, and in the worst cases, loss of structural integrity and resultant safety risks. Amongst these, the most common cause of deterioration is corrosion of reinforcing steel, refer Figure 1.

Most concrete structures and buildings require repair and protection during their service lives. Some structures and buildings may be at or beyond their design lives however, decades of future service lives are required for sustainability and economic reasons, so pro-active, engineered, maintenance and corrosion management approaches are necessary.

Various concrete repair and protection technologies exist with new approaches continually being developed and offered. When independent, experienced, consulting engineers are involved on projects then scenario analyses of remedial, maintenance and corrosion management options can be utilised to enable informed decisions by structure and asset owners. The maintenance and corrosion management approaches then selected by the owners can be engineered and tailored to meet required future structure service lives, budgetary constraints, and maintenance funding release at lowest life cycle costs. Independence and experience are not always employed on structure and building concrete repair and protection projects in Australia. Bias towards particular products and technologies is considered more common, even by consulting engineers and corrosion consultants that promote themselves as being independent. As such, mistruths, bold claims, misstatements and misconceptions about some aspects of concrete repair and protection have become prevalent.

There are some overlooked issues of some concrete repair and protection technologies including:- incipient anode management, concrete patch repair performance, migrating organic inhibitors, penetrants, coatings, galvanic anodes and the recently developed hybrid system. Some facts are derivable from the literature and in some instances literature of many decades past. Other facts lie in fundamental corrosion science (electrochemistry).

Figure 1: Reinforcement corrosion induced deterioration.

Protection afforded to reinforcement by concrete
As mentioned, the highly alkaline environment in concrete results in the formation of a passive oxide film on reinforcing steel which protects it from corrosion. The hydraulic binder of concrete commonly consists of Portland cement or of mixtures of Portland cement and one or more of fly ash, ground granulated iron blast-furnace slag or silica fume[1]. The latter are referred to as Blended cements.

The reaction of the cement compounds of Portland cement or Blended cement with water results in the setting and hardening of the cement paste so that it binds the aggregate (coarse and fine) of the concrete together. A product of the hydration of Portland and Blended cements is $Ca(OH)_2$ together with NaOH and KOH. As a result, the pH of the pore solution of concrete is normally in the range of 12-14[2-6].

For iron (steel) in a pH 12-14 alkaline environment, thermodynamics, the science of energy changes, tells us that the metal will be passive. Kinetics, or rates of possible reactions, then confirm that when steel in concrete is passive a very low corrosion rate exists.

Current densities measured for passive reinforcing steel in concrete are of the order of 0.1 $\mu A/cm^2$ [7,8]. This current density therefore corresponds to an insignificantly slow corrosion rate of 1.2 µm/year. This corrosion rate is of the order of 1 mm in 1,000 years and so it can be seen that the reinforced concrete structure or building element may be regarded as unaffected by corrosion.

In addition to providing a high pH passivating environment for reinforcing steel, concrete also provides a physical barrier against the ingress of corrosion-inducing substances via the aqueous phase, and a relatively high electrical resistivity, which reduces the corrosion current and hence the rate of corrosion if corrosion is initiated.

Corrosion of reinforcement
The passivity provided to reinforcement by the alkaline environment of concrete may be lost if the pH of the concrete pore solution falls because of carbonation or if aggressive ions such as chlorides penetrate in sufficient concentration to the steel reinforcement surface. Carbonation of concrete occurs as a result of atmospheric CO_2 gas (and atmospheric SO_x and NO_x gases) neutralising the concrete pore water (lowering its pH to 9) and thereby destroying the passive film.

Leaching of $Ca(OH)_2$ (and NaOH and KOH) from concrete also lowers pH to allow corrosion of reinforcement to occur.

Chloride ions break down the passive oxide film on reinforcing steel resulting in pitting corrosion. Suggested mechanisms of passive film breakdown are beyond the scope of this paper but can be found in various references[9]. The electrochemical corrosion reactions that then occur have been illustrated and discussed in various references[6,9]. The composition of the passive film is similarly discussed in these same references.

The exact nature of reinforcing steel corrosion products (rusts) varies markedly depending on conditions. Corrosion products have various layers and are of various compositions. Generally speaking they will be layers and combinations of ferrous and ferric hydroxides, hydroxyl/oxides and oxides each with varying degrees of hydration possible[6,9]. If the concrete has suffered from inward diffusion of SO_x then a range of hydroxy sulphates will also be present in the matrices.

The process of reinforcement corrosion will lead to corrosion products which will occupy a greater volume than the iron dissolved in its production. Furthermore, when the corrosion products become hydrated the volume increase is even greater[6].

The consequence of higher volume corrosion products is then to develop tensile stresses in the concrete covering the reinforcement. Concrete, being weak in tension, will crack as a consequence of the corrosion, refer Figure 1. Continuing formation of corrosion product(s) will enhance the expansion which will ultimately lead to cracked pieces of concrete cover detaching leading to delamination and then spalling, refer Figure 1. Rust staining of the concrete may or may not occur together with the cracking or as a prelude to delamination and spalling, refer Figure 1. Section loss of the reinforcement also occurs as a result of the corrosion, refer Figure 1.

It is most important to note however, that not all corrosion of reinforcement leads to rust staining, cracking, delamination or spalling of cover concrete. Localised pitting corrosion, localised corrosion at cracks, localised corrosion at concrete defects, localised pitting corrosion to pre-stressing steel, etc. can result in marked section loss and ultimately structural failure without the visible consequences of corrosion on the concrete surface (i.e. no rust staining, cracking, delamination or spalling of cover concrete)[10].

Broomfield[6] also notes that 'black rust' or 'green rust' (due to the color of the liquid when first exposed to air after breakout) corrosion can also be found under damaged waterproof membranes and in some underwater or water saturated structures. He states that it is potentially dangerous as there is no indication of corrosion by cracking and spalling of the concrete and the reinforcing steel may be severely weakened before corrosion is detected. Reinforcement bars may be hollowed out in such deoxygenated conditions particularly under membranes or when water is permanently ponded on the surface.

Concrete repair and protection
Extended performance is expected of our concrete structures and buildings: some are in extremely aggressive environments, they may be many decades old, they are of critical importance in terms of function or location, they are irreplaceable, etc. such that some require repair and protection during their service lives. During the lifetime of a reinforced concrete structure, two basic periods with respect to corrosion and corrosion protection of reinforcement can be defined. The initiation period (t_0), when critical or threshold amounts of chlorides have not reached the reinforcement, when carbonation has not progressed to reinforcement depth, when the extent of leaching has not lead to a lowering of pH, etc. so that the reinforcement remains passive, and the propagation period (t_1) when reinforcement corrosion proceeds. This corrosion model was first proposed by Clear[11], see Figure 2, and has since been developed by others[3,6,12].

Various technologies and repair approaches are then possible during the initiation period (t_0) and the propagation period (t_1) of a reinforced concrete structure, building or element. Figure 3 presents a summary of some technologies and repair approaches. It is beyond the scope of this paper to discuss each of these technologies, but what will be discussed are some aspects of concrete patch repair, penetrants and coatings, migrating organic inhibitors, galvanic anodes and hybrid treatment.

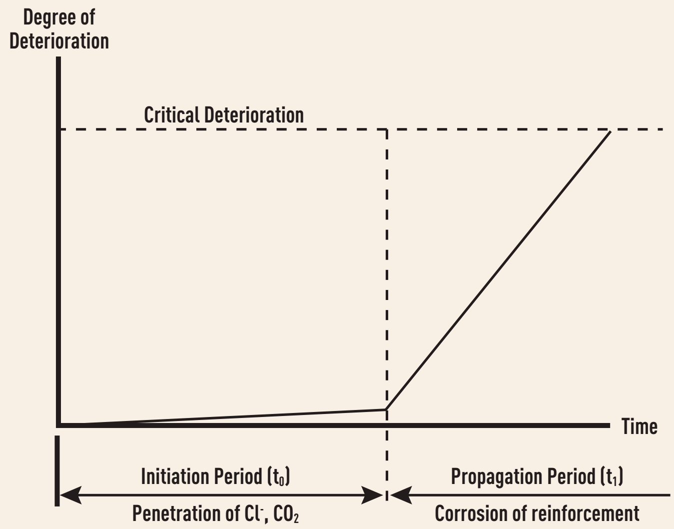

Figure 2: Model for the reinforcement corrosion sequence in concrete[11].

Patch repair

Concrete patch repair, conventional concrete repair, conventional patch repair, patch repair, patching, etc. are all descriptions of a common repair technique for reinforced, precast and pre-stressed concrete structures and building elements suffering from reinforcing steel corrosion. Patch repair involves removal (or breakout) of physically deteriorated concrete (by mechanical tools or ultra-high water pressure), cleaning the steel within the patch, application of a coating system to the steel, priming of repair area surfaces and finally restoring the concrete profile, typically with a polymer-modified cementitious based repair mortar (hand-applied, poured, sprayed or combinations thereof)[10].

Breakout of concrete at repair areas needs to go behind reinforcement (by up to 15-25 mm) and along reinforcement until un-corroded (for at least a distance of 50 mm minimum). Consequent reinstatement with polymer-modified cementitious based repair mortar or high-durability repair concrete will then render the reinforcing steel within the repair area passive[13].

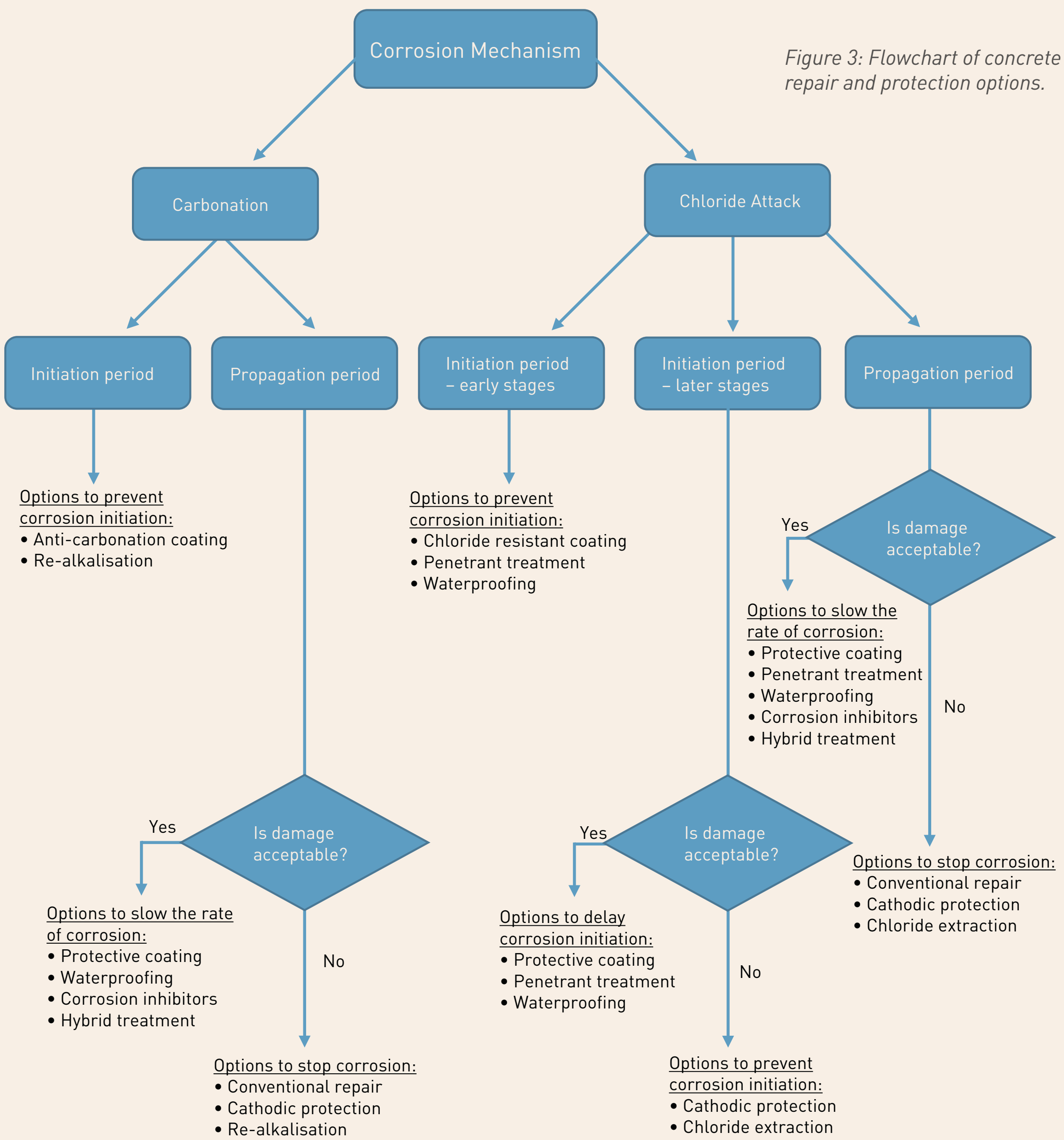

Figure 3: Flowchart of concrete repair and protection options.

However, when it comes to patch repair of concrete structures and buildings, it would be remiss not to discuss briefly the phenomenon of 'incipient anodes'.

In many instances, corrosion-induced deterioration has subsequently been observed in the parent concrete in the immediate area around the patch repairs, sometimes within a "few months to a few years" following completion of the repair process[14]. This phenomenon has been termed the' incipient anode', 'ring anode' or 'halo' effect[15], refer Figure 4. Page and Treadaway[2] were the first to suggest that the mechanism of incipient anode formation in chloride-contaminated concrete is the concept of macro-cell development (the formation of spatially separated anodes and cathodes with the anodes being the areas adjacent the repair and the cathodes being the repair itself). For the more than 30 years since, the macro-cell development mechanism has almost exclusively been considered in the corrosion literature as the cause of incipient anode formation.

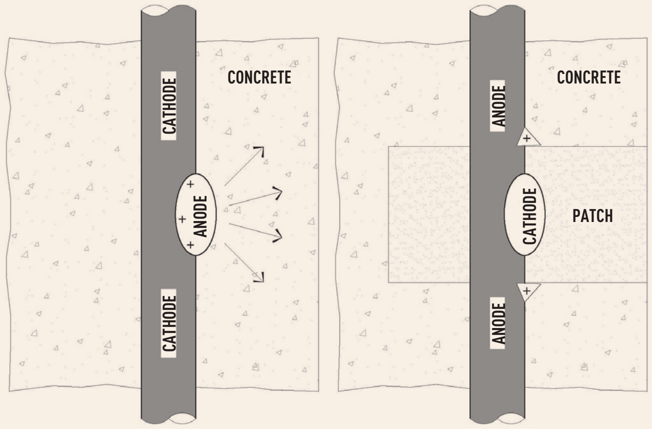

Figure 4: Incipient anode schematic[6] (but note no rebar coating and/or bonding agent to 'isolate' patch).

Christodoulou et. al.[16] have recently questioned the macro-cell development mechanism of incipient anode formation in chloride-contaminated concrete. They assessed the impact of macro-cell activity on the formation of incipient anodes around the perimeter of repairs in a patch-repaired reinforced concrete multi-story car park and a patch-repaired reinforced concrete bridge. They found that the potentials of the steel reinforcement within the repairs were more negative (by 100's of millivolts) than the potential of steel in the adjacent parent concrete. This is the opposite of the Page and Treadaway[2] macro-cell activity mechanism where the potentials of steel within repairs were suggested to be less negative (i.e. more positive) than potentials in adjacent parent concrete areas.

Christodoulou et. al.[16] propose that the macro-cell activity is primarily a consequence of incipient anode formation and the cause may reside in one or more of the following reasons:

- Chlorides may enter the concrete through the interface between the parent concrete and repair material;
- The parent concrete adjacent to the repair area has a level of chloride contamination that is sufficient in its own to cause corrosion; and/or
- Preparation of a repair area may result in vibration damage at the steel interface with the adjacent parent concrete.

Furthermore, they claim a review of the literature did not identify any data to support the macro-cell activity hypothesis where the steel potential in the repair rises above (is less negative) than the potential in the parent concrete surrounding the repair thereby causing an incipient anode to form adjacent to the repair. However, it is noted, for example, that Pruckner and Gjorv[17] report that potentials can be less negative in repair areas by as much as 500 mV. Dugarte and Sagues[18] state that the transition to the passive condition within repair areas elevates the potential of the steel in the patch from its former highly negative value to one that can be several hundred mV more positive. Nounu and Chaudhary[19] and Hussain et. al.[20] measured potentials in the repair that are less negative than the potential in the parent concrete surrounding the repair. Soleimani et. al.[21] state that the corrosion potential of steel in a patch can be much higher than surrounding concrete. Broomfield[6] supports the Page and Treadaway[2] mechanism. Green et. al.[10] report that the industry in Australia does accept the Page and Treadaway[2] mechanism and that Australian operators have typically measured steel potentials in repair areas that rise above (are less negative) than the steel potentials in parent concrete surrounding repairs.

When it comes to incipient anode management, Green et. al.[10] report that there is a perception and/or misconception in the industry (in Australia but also possibly elsewhere) that the only way to manage them is by the insertion of anodes within patch repairs.

These authors point out that it should be remembered that conventional concrete patch repair utilising a reinforcement coating system (zinc-rich epoxy, epoxy or resin modified cementitious), a bonding agent (acrylic, styrene butadiene rubber, epoxy or polymer modified cementitious) and a polymer modified cementitious repair mortar (hand-applied, poured, sprayed or combinations thereof), effectively 'isolate' the patch such that macro-cell activity is minimised and incipient anode formation managed. By the use of reinforcement coating systems, cathodic reactions cannot be sustained, or are severely restricted, on the steel surfaces within the patch. Bonding agents provide a restriction to ionic current flow out of the patch into the surrounding parent concrete. Furthermore, polymer modified cementitious repair mortars have electrical resistivities which restrict ionic current flow between the patch and surrounding parent concrete.

Green et. al.[10] further advise that if all three aspects, reinforcement coating/bonding agent/repair mortar, are effectively combined, then macro-cell activity is minimised. Even if just a reinforcement coating and just a polymer modified cementitious repair mortar are used, without the use of a bonding agent (but with the method of surface preparation of repair surfaces being saturated-surface-dry, SSD), these authors consider that macro-cell activity will still be minimised.

These authors also report on research from others (Morgan[22]) done in the 1980s and 1990s (i.e. many decades past) involving polymer modified Portland cement mortars with high electrical resistivity achieving corrosion protection and in addition not affecting corrosion of steel in adjacent unrepaired areas (i.e. not leading to incipient anode development). Also, Morgan[22] studied in the mid-1980s the influence of a variety of different reinforcement coating systems on corrosion activity. He concluded that a low permeability polymer modified repair mortar used in conjunction with a zinc-rich epoxy rebar coating provides the best protection to reinforcing bars both in the repair zone and in the adjacent concrete.

Furthermore, Green et al.[10] report of the work of Berndt[23] on the long-term performance (in excess of 35 years) of various repair techniques to the reinforced concrete piles (500 mm diameter) of two large (260 m long and 48 m wide) reinforced concrete sugar storage sheds in Cairns, Queensland, Australia. Deterioration to the 2,118 reinforced concrete piles included a combination of reinforcement corrosion, alkali-silica reaction and salt hydration distress (or physical salt attack). Berndt[23] states that patch repairs with shotcrete up to 39 years old were generally successful and devoid of incipient anode problems except where the removal of chloride contaminated concrete around repair areas was inadequate.

Patch repair performance

The authors have been to quite a number of conferences, seminars and technical meetings in recent years where some specialist contractors, some consulting engineers and some corrosion consultants are claiming patch repairs are not durable and delaminate and spall within a "matter of years". Typically they are talking of chloride-contaminated (chloride corrosion affected) reinforced or pre-stressed concrete structures and not carbonation affected structures. It is noted however, that patch repairs have been durable for many decades in aggressive environments and it is beyond the scope of this paper to cite the likely widespread literature confirming this but some examples can be discussed.

Morgan[22], for example, reports of a 1990 study of some 60 concrete bridges across Canada with shotcrete repairs ranging in age from 8 to 30 years. They noted that in spite of the wide variety of different shotcrete repair materials used, the study found virtually no examples of corrosion induced deterioration in the repair areas. A few structures were found where continuing exposure of the patch and adjacent concrete to seepage from snowmelt carrying chloride-based deicing salts had led to renewed corrosion of the original concrete adjacent to the shotcrete patch areas. Similar corrosion could however, also be found in adjacent elements which had not been patch repaired. They then advise that this indicates that under the exposure conditions prevailing, ongoing corrosion in the original concrete would probably have occurred irrespective of whether the structures were repaired or not. They further advise that a small percentage of the 60 concrete bridges examined had deteriorated in the patch areas, but this could be attributed to poor design and/or construction practices such as feather-edging of the repairs, lack of adequate surface preparation or ongoing deterioration in non-freeze/thaw durable substrate concretes below the patches. Overall, they state however, most of the repairs were in good condition and had adequately reinstated the serviceability of the bridges.

Atkins et. al[24], for example, report of some "holding repairs" to ensure public safety on a major reinforced concrete bridge suffering from both carbonation and chloride attack (from deicing salts). They state that conventional patch repair is usually little more than an aesthetic exercise and patch repairing is effective only in the short term. However, the type of "holding repair" that was designed involved removing loose and delaminated concrete using hand held breakers and applying a polymer modified cementitious mortar to the areas exposed. Even given the "primitiveness" of these repairs (i.e. no rebar coating system and/or no bonding agent), Atkins et. al.[24] report that they were all performing adequately and had prevented significant reinforcement section loss occurring over a period of 10 years. It is also noted that Atkins et. al.[24] designed the "holding repairs" as part of an overall long-term repair strategy for the bridge that centered around the use of impressed current cathodic protection (CP).

As mentioned previously, Berndt[23], for example, reports on the long-term performance (in excess of 35 years) of various repair techniques to the previously described reinforced concrete piles of two large reinforced concrete sugar storage sheds in Cairns, Queensland, Australia. Repairs and product trials included shotcrete, unreinforced concrete collars, cementitious waterproofing slurry, organic coatings and sealers. In terms of the shotcrete patch repairs, Berndt[23] reports that patch repairs using shotcrete undertaken in the 1970s (i.e. up to 39 years old at the time of publishing the paper) had performed well and that the failure rate was ~10%. Repairs conducted since 1987 and up to 25 years old (at the time of the publishing of the paper) had a failure rate of ~4%. Failure was defined as reinforcement corrosion (chloride) induced cracking, delamination or spalling. Berndt[23] then surmises that the reason for failure was due to insufficient removal of chloride contaminated concrete prior to repair. It is advised that repairs to the storage shed piles are ongoing and the technical specification for repair incorporated lessons learnt from the performance of prior repairs including removal of concrete from at least 25 mm behind reinforcement and along the length of reinforcement to expose at least 50 mm of un-corroded steel.

Our experience indicates that repairs specified to include a reinforcement coating system (zinc-rich epoxy, epoxy or resin modified cementitious), bonding agent (acrylic, styrene butadiene rubber, epoxy or polymer modified cementitious) and a polymer modified cementitious repair mortar (hand-applied, poured, sprayed or a combination thereof) will have many decades of performance even in aggressive coastal marine environments with chloride exposure. Patch repairs with reinforcement coating systems (zinc-rich epoxy, epoxy or resin modified cementitious) and polymer modified cementitious repair mortars (hand-applied, poured, sprayed or combinations thereof) will also have many decades of performance.

We would argue, like Morgan[22], that where patch repairs (hand-applied, poured or sprayed) have not been durable and have cracked, rust stained, delaminated or spalled within a "matter of years" that such abysmal performance would be attributable to poor design and/or construction practices, refer Figure 5.

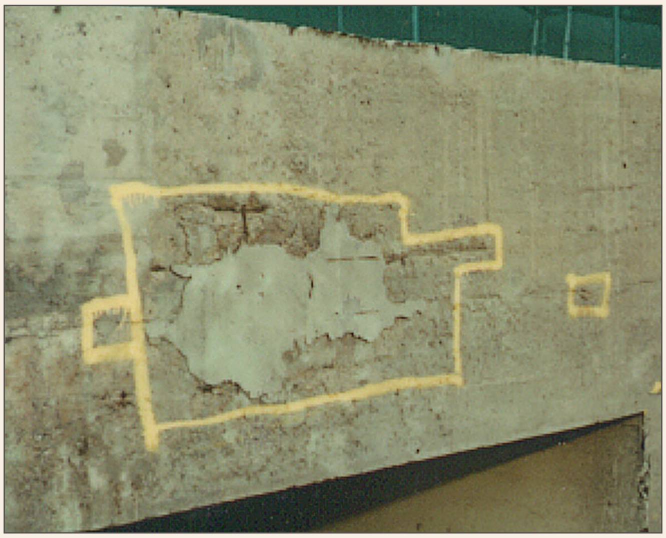

Figure 5: Abysmal patch repair performance and incipient anode development due to poor design (no isolation of repair area using a rebar coating and/or bonding agent) and poor construction practices (feather edging of repair, poor compaction, inadequate curing).

Corrosion inhibitors
It is to the migrating organic inhibitors that specific focus is to be applied. These systems are more widely available than at any time previously. Peek et. al.[25] advise that migrating organic inhibitor materials are intended to be applied in one of three ways:

- As a surface applied ("topical") treatment from which the active constituent moves through the concrete cover to establish protection of the embedded reinforcement, refer Figure 6.
- As a treatment injected into the concrete, where the active constituent moves through the concrete to establish protection of the embedded reinforcement.
- As a component of patch repair materials, where the active constituent moves out of the patch or overlay and through the adjacent parent concrete to establish protection of the embedded reinforcement.

Figure 6: 'Topical' application of migrating organic inhibitor to concrete.

It is also understood that migrating organic inhibitors have been incorporated into some surface penetrant (i.e. silicon chemistry based) systems for concrete as well as some surface coating (organic film-forming) systems for concrete.

Green et. al.[10] advise that their concern is that these materials are being specified and/or applied to reinforced and pre-stressed concrete structure and building elements without an understanding of some of the performance concerns including:

- Extent of migration?
  (concrete moisture content; concrete porosity; exposure effects; ambient conditions)
- Can they migrate in a suitable timeframe?
- Can you readily measure their locale?
- Longevity?
  (ongoing migration; back diffusion to the environment; evaporation; rinsing or leaching of the surface)
- Stability?
  (how long will they continue to perform; are they consumed)
- Accelerate corrosion?
  (insufficient concentration; partly-cover rebar; different concentrations due to concrete porosity; macro-cell corrosion due to inhibitor concentration differences; large cathode/small anode effects)
- What effect on localised pitting corrosion?
  (pits in chloride-contaminated conventional reinforcement; pits in chloride-contaminated pre-stressing steel)
- Excessive applications can cause chemical attack of concrete surfaces?

Electrochemistry can be utilised to show how the use of these materials, including within penetrant and coating systems, can accelerate corrosion. Green et. al.[10] discuss such issues and advise that there are views in the industry in Australia that applying migrating organic inhibitors to structures and buildings (on their own or followed by the application of a surface coating system), by adding them to repair mortars, by incorporating them into penetrant and coating systems for concrete, etc. that "it can't hurt" and it is "belt and braces". Literature from independent investigators together with an understanding of some fundamental corrosion science (electrochemistry) issues show that they "can hurt" and a "belt and braces" attitude is not a sound engineering approach.

An example is consideration of the effects of migrating organic inhibitors on localised pitting corrosion of reinforcing steel in concrete. As mentioned previously, localised pitting corrosion of reinforcing and pre-stressing steel in concrete is caused by chloride ions however, localised pitting corrosion of reinforcing and pre-stressing steel in concrete is also possible where carbonation has progressed down cracks or at local concrete defects and leaching of the alkalis of concrete has occurred at cracks and local concrete defects. Localised pitting corrosion may also be caused by stray direct current (DC) interference.

Green et. al.[10] propose that for a migrating organic inhibitor to have an effect on, for example, the potentially rapid pitting of reinforcing or pre-stressing steel in chloride-contaminated concrete, it would need to impact dramatically on the anodic process (within the pits themselves, under acidic conditions and with potentially very narrow pit entries), impact the cathodic process (affect the oxygen reduction reaction on the metal surface) and/or impact the electrolytic path between cathodic sites and pits, or a combination(s) thereof. If they weren't to impact then one may not know as localised pitting can result in marked section loss and ultimately structural failure without the visible consequences of corrosion on the concrete surface (i.e. no cracking, delamination or spalling of cover concrete).

Green et. al.[10] further advise that migrating organic inhibitors could also accelerate pitting corrosion due to differences in inhibitor concentration at steel surfaces, insufficient concentrations of inhibitor at steel surfaces, the inhibitor may only partly-cover steel surfaces, etc.

Penetrants and coatings
The principal issue to be touched upon in terms of the use of penetrants and coatings in concrete repair and protection is that their application will not necessarily reduce the rate of reinforcing or pre-stressing steel corrosion but could accelerate it. Fundamental corrosion science (electrochemistry/kinetics) principles can be used to explain how applying a penetrant system or a coating system to concrete could accelerate corrosion.

Green et. al.[10] report that it is not uncommon to hear in the industry in Australia that a reason for applying a penetrant system (e.g. a silicon chemistry based material – silane, siloxane, silicone or blends thereof) and/or a surface coating system to a reinforced or pre-stressed concrete structure or building element, is to "dry the element out, increase the resistivity of the concrete and thereby reduce corrosion rate". They advise, from a fundamental corrosion science (electrochemistry) point of view, this is not unreasonable if the resistance between anodic and cathodic areas (resistance control kinetics), which is dominated by the concrete resistivity (ionic current flow through the porewater/electrolyte), does increase. A conceptually derived Evans diagram (E – log I diagram) was used by Green et. al.[10] to show the effect of increasing electrolytic resistance (resistivity) of concrete between anodic and cathodic areas on both corrosion current (rate) and anode and cathode potentials. Consequently, an increase in the anode/cathode resistance leads to a reduction in corrosion current flow and hence corrosion rate.

Green et. al.[10] then noted that if the application of a penetrant system and/or a surface coating system to a reinforced or pre-stressed concrete structure or building element does have an effect of "drying it out" then it will also mean increased oxygen access into the concrete and consequently onto reinforcing or pre-stressing steel surfaces. The availability of oxygen is of considerable importance since the predominant cathodic reaction for the corrosion of reinforcing and pre-stressing steel in concrete is the reduction of oxygen. A conceptually derived Evans diagram was again used by Green et. al.[10] to show the effect of increasing oxygen availability to the steel surface (and increasing cathodic polarisation) whereby for the oxygen reduction reaction operating with increasing oxygen supply, the corrosion rate increases and the corrosion potential gets less negative (more positive).

Thus it was shown that the application of a penetrant system and/or coating system to a reinforced or pre-stressed concrete element must result in an increase in concrete resistivity that more than offsets the associated increase in corrosion rate due to increased oxygen transport. If this is not the case, Green et. al.[10] advise that there will be an increase in overall corrosion rate. Furthermore, they concluded that penetrants and coatings should therefore not be blindly specified without an understanding of the fundamental corrosion science (electrochemistry/kinetics) principles that will apply to the reinforced and pre-stressed concrete elements that are being remediated.

Cathodic protection

Sir Humphry Davy, refer Figure 7, was the founder of practical cathodic protection (CP). Davy postulated in January 1824[26], that it would be possible to prevent corrosion of copper sheathing on ships by connecting it to zinc, tin or iron[27]. This was based on his observations and conclusions from over two decades of working with galvanic couples and he certainly considered the beneficial effects for the more positive metal in the couple at least as early as 1812[27]. The copper sheathing on the ships was needed to reduce fouling and prevent attack on the timber by worms. Davy then reported on full-scale trials in June 1824[28] and showed the complete effectiveness of zinc and iron in protecting the copper[27]. He also published in June 1825[29] the influence of ship movements on the efficiency of the protective action and the effects on fouling[27].

Davy's work defined the two ways in which we apply CP to this very day, by using galvanic anodes or by imposing impressed current where current is forced from an anode through the electrolyte onto a structure (cathode) using a DC power supply[27]. Both methods of CP act to shift the potential of the structure to be protected in the negative direction. The anode is consumed while the cathode is protected if there is sufficient current to provide the requisite polarisation[27].

Figure 7: Sir Humphry Davy.

There are various galvanic anode types for the provision of cathodic current to reinforcing steel (or pre-stressing steel) in concrete[9]. The extent of cathodic current provision by such anodes may or may not lead to CP per se in accordance with concrete CP standards[30,31].

Holloway et. al.[32] point out that galvanic anode systems for concrete, have not necessarily provided CP in a range of applications. They advise that the performance of a galvanic anode for reinforced and pre-stressed concrete depends largely on various parameters including:

- Humidity and moisture in the concrete.
- Temperature.
- Anode geometry and spacing.
- pH around anode.
- Chemicals added around anode to maintain an activated state.
- Current density respective to anode surface area.
- Resistance of anode to concrete.
- Build-up of corrosion products around anode.
- Level of chloride contamination.
- Level of corrosion activity of the reinforcement.

Galvanic anodes may therefore only provide some cathodic current and hence some reduction in corrosion rate and not provide CP in accordance with the criteria required by accepted standards and codes[30,31].

Holloway et. al.[32] go on further to say that there are some key gaps in the general understanding that need to be addressed including:

- Suitable monitoring methods for determining the performance of concrete galvanic anode systems, especially if they do not meet protection criteria, need to be assessed and accepted by the greater community. While corrosion rate monitoring may provide one option, they note that this method could prove difficult to apply and requires a much more detailed understanding of the electrochemical response of steel in concrete so as to be applied proficiently.

- Independent and robust long term studies on the actual performance of concrete galvanic anode systems. Many of the papers available in the literature have been authored or co-authored by representatives from the anode manufacturing companies. They propose that independent, academic and industry based studies will provide a more objective view on performance and their relative limitations and that this knowledge could only assist in the successful implementation of such systems.

- Furthermore, they advise that the mechanistic aspects, which underpin the efficacy of galvanic concrete CP, remain unclear. They considered this not necessarily a negative issue, but one that would need to be addressed by future works in a scientific setting.

Hybrid treatment

In the last 5 years or so, what have been termed "hybrid CP or hybrid anode systems", have emerged in Australia, These systems were developed primarily in the UK[33] and involve an array of embedded Zn anodes that are operated in impressed current mode initially (for a number of weeks) and then in galvanic mode[33].

The use of a hybrid anode is referred to in the international standard BS EN ISO 12696[31] which provides CP criteria for steel in concrete namely, at any representative steel in concrete location, any one of the following criteria shall be met:

- An "Instantaneous Off" potential more negative than -720 mV with respect to a Ag/AgCl/0.5M KCl; or

- A potential decay over a maximum of 24 h of at least 100 mV from "Instantaneous Off"; or

- A potential decay over an extended period (typically 24 h or longer) of at least 150 mV from "Instantaneous Off" subject to a continuing decay and the use of reference electrodes (not potential decay probes) for the measurement extended beyond 24 h.

If any one of these criteria are not achieved, then BS EN ISO 12696[31] requires that a further assessment of corrosion risk shall be made. A Note (Note 9 at Clause 8.6 of BS EN ISO 12696[31]) then advises that a means of assessing corrosion risk is to estimate the steel corrosion rate by inserting the applied current density and steel potential shift into the Butler Volmer equation[33]. The applied current density is obtained from the current delivered from a small segment of the anode system and an estimate of the steel potential shift is given by the potential decay measured at the same anode segment.

Green et. al.[10] point out that there are views in the industry in Australia that when hybrid systems achieve a corrosion rate of less than 2 mA/m^2 that cathodic protection in accordance with BS EN ISO 12696[31] is being provided. They advise that this is not the case and what is the case is that estimating corrosion rate is an "assessment of corrosion risk" and not an indication of cathodic protection. Green et. al.[10] surmise that if cathodic protection is to be achieved to BS EN ISO 12696[31] by a hybrid system then one of the three criteria listed above shall be met at each and every representative steel in concrete location.

Green et. al.[10] propose that "hybrid CP" systems for concrete are more correctly termed "hybrid treatment" and not "hybrid CP" as CP in accordance with standards or codes[30,31] may not necessarily be achieved but rather a corrosion rate reduction.

Furthermore, it is noted that Holloway et. al.[32] advise that there are some similar key gaps in the general understanding of hybrid systems (as for galvanic anode systems) including:

- Independent and robust long term studies on actual performance. Many of the papers available in the literature have been authored or co-authored by representatives from the anode manufacturing company. They propose that independent academic and industry based studies will provide a more objective view on performance and their relative limitations and that this knowledge can only assist in the successful implementation of such a system.

- How the performance and technology of hybrid systems perform in a mechanistic sense, remains unclear. They do not necessarily consider this a negative issue, but one that would need to be addressed by future works in a scientific setting.

Conclusions

There are some overlooked issues with some concrete repair and protection technologies including:- incipient anode management, concrete patch repair performance, migrating organic corrosion inhibitors, penetrants, coatings, galvanic anodes and the recently developed hybrid system.

It is proposed that it should be remembered that conventional concrete patch repair utilising a reinforcement coating system, a bonding agent (or not and just saturated surface dry) and a polymer modified cementitious repair mortar should effectively 'isolate' the patch such that macro-cell activity is minimised and incipient anode formation managed.

Patch repairs with reinforcement coating systems and polymer modified cementitious repair mortars will have many decades of performance. It is proposed, that where patch repairs have not been durable and have cracked, rust stained, delaminated or spalled within a "matter of years" that such would be attributed to poor design and/or construction practices.

It is considered a concern that migrating organic inhibitors are being specified and/or applied to reinforced and pre-stressed concrete structures and buildings without an understanding of some of the performance issues including:- extent of migration; can they migrate in a suitable timeframe; can you readily measure their locale; longevity; stability; will they accelerate corrosion; what effect do they have on localised pitting corrosion; and, excessive applications can cause chemical attack of concrete surfaces.

In terms of the application of a penetrant system and/ or coating system to a reinforced or pre-stressed concrete element, it should be remembered that they must result in an increase in concrete resistivity that more than offsets the associated increase in corrosion rate due to increased oxygen transport as moisture content decreases. Otherwise, there will be an increase in overall corrosion rate.

It should be noted that systems involving galvanic anodes for reinforced and pre-stressed concrete, most particularly those relating to embedded zinc anodes, may provide some cathodic current and hence some reduction in corrosion rate and not necessarily cathodic protection per se to Australian or International standards and codes.

Similarly, hybrid systems for concrete may not provide cathodic protection in accordance with Australian or International standards or codes but rather a corrosion rate reduction.

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