INNOVATIVE SOLUTIONS FOR REINFORCEMENT CORROSION

PARCHEM CONSTRUCTION SUPPLIES

Providing innovative corrosion solutions to the Australian construction market for over 10 years.

VECTOR®

VECTOR CORROSION TECHNOLOGIES

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CORROSION BASICS

INNOVATIVE SOLUTIONS FOR REINFORCEMENT CORROSION

Parchem Construction Supplies have been providing innovative corrosion solutions to the Australian Construction market for over 10 years. It started in 2001 with the Galvashield XP anode and has since grown to over 10 different product options including galvanic corrosion protection systems, impressed current cathodic protection systems and electrochemical protection systems.

This wide product range on offer gives asset owners and engineers an unrivalled choice of proven technologies when considering a particular corrosion mitigation strategy.

Complemented with an extensive selection of concrete repair mortars and protective coatings, Parchem delivers the complete concrete rehabilitation package. This package can be tailored to the specific requirements of the structure considering all technical, environmental and commercial factors.

Parchem Construction Supplies in conjunction with Vector Corrosion Technologies can provide the service and support that is needed to provide detailed specification assistance through to on site support for your project. With a product range that has been tested and monitored in Australia's harsh marine environment and shown to provide long term protection to numerous structures throughout the country, Parchem and Vector have the product range and experience to provide the most cost effective solution.

What is corrosion?

Corrosion can be described as the deterioration of a material, usually a metal, by a chemical or electrochemical reaction within its environment. In this case we are looking at corrosion of steel reinforcement in concrete. When steel is embedded in concrete, a passive oxide film forms upon its surface. This film is maintained by the alkaline nature of the concrete (typically in excess of pH 12.6). While this passive film is present, the steel is immune to corrosion and therefore gives stability to a structure. However, when the environment becomes contaminated the local or global pH of the concrete can fall, causing passivity to be lost and corrosion to occur.

What causes corrosion?

A number of everyday contaminants can cause corrosion:

- Airborne chlorides
- Seawater
- Carbon dioxide in the atmosphere
- Sea-dredged aggregates
- Chloride containing admixtures

Parchem Construction Supplies is proud to be active members of the following industry associations.

CONCRETE INSTITUTE of AUSTRALIA

AUSTRALASIAN CORROSION ASSOCIATION INC. SEMPER TUENS

acra Australian Concrete Repair Association

CORROSION IN A MARINE ENVIRONMENT

Areas of vunerability

Areas prone to corrosion on a marine structure can be categorised into three areas:

- **Atmospheric zone**
  This is reinforced concrete located in the vicinity of the marine environment, but not in direct contact with water; i.e. bridge decks, soffits and beams. These elements often display moderate corrosion rates due to the presence of airborne moisture and chloride.
- **Splash and tidal zone**
  This is the area located on and around the water line and is often classed as semi-submerged; i.e. concrete piles and piers. These elements generally experience the most severe corrosion due to the high moisture, oxygen availability and wet/dry cycling.

Telltale signs of corrosion in these two zones are cracking, spalling and red rust staining.

- **Submerged zone**
  This is reinforced concrete permanently located underwater, i.e marine piles. These areas can experience lower levels of corrosion due to reduced oxygen levels. However, while corrosion here is less aggressive, submerged areas are at risk from another problem known as black rust and low water corrosion.

What happens when corrosion occurs?

During the corrosion process, a by-product is formed (rust), which occupies a volume seven times greater than that of the native metal. This volume change causes cracking and eventual spalling of the concrete surface.

Corrosion in the marine environment

The majority of Australia's infrastructure can be classed as being in a marine environment. This environment is extremely aggressive in nature due to the abundance of both chloride and moisture. Areas such as beams, soffits and concrete piles generally experience the highest level of deterioration with the most vulnerable areas being located in the tidal/splash zone. The rate of corrosion can be accelerated further by variations in water composition, temperature, oxygen concentration, marine growth and water flow.

CORROSION PROTECTION OPTIONS

Selecting a Corrosion Protection Strategy for Concrete Structures

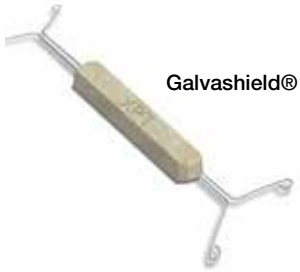
Selecting the appropriate level of corrosion protection is based on many factors such as the level of chloride contamination and carbonation, amount of concrete damage, location of corrosion activity (localized or widespread), the cost and design life of the corrosion protection system, and the expected service life of the structure. The following levels of protection can be used as a guide to decide the most effective strategy.

Corrosion Prevention

Corrosion prevention is used to prevent corrosion activity from initiating in contaminated concrete.

In concrete repair projects, the removal and replacement of damaged concrete if completed in accordance with industry guidelines will addresses the areas with the highest levels of corrosion. However, new corrosion sites are likely to form in the surrounding contaminated concrete which was passive before the repairs. To mitigate new corrosion activity from occurring around concrete repairs or at other interfaces between new and old concrete such as bridge widening, joint repairs and slab replacements, a simple localized corrosion prevention strategy utilizing with **Galvashield® XPT** or **Galvashield® XP2** embedded galvanic anodes, can extend the life of concrete repairs.

Galvashield® XP2

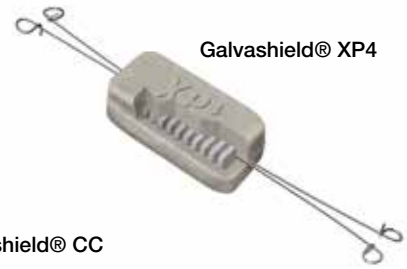


Galvashield® XPT

Corrosion Control

Corrosion control systems are utilized where corrosion has initiated but corrosion has not yet progressed to the point of causing concrete damage. **The use of corrosion control systems will either stop on-going corrosion activity or provide a significant reduction in the corrosion rate and an increased service life of the rehabilitated structure.** In many cases, this level of protection can be provided with low incremental cost as the protection can be targeted at specific areas of contamination or corrosion activity. **Galvashield® XP2 and XP4** anodes can be used in corrosion control or corrosion prevention applications. **Galvashield® CC** anodes are used to provide targeted galvanic corrosion control to columns, beams, decks, post-tensioned anchorages and other structures where on-going corrosion activity threats the service life of the structure. **Galvanode® DAS** anodes can also be used in concrete overlays, concrete jacketing and other concrete repair applications to provide long lasting galvanic protection.

Galvashield® CC



Galvashield® XP4

Cathodic Protection

Cathodic protection provides the highest level of protection and is intended to stop on-going corrosion activity. Cathodic protection should be selected when the highest level of protection is necessary and the cost economically justified. Cathodic protection systems are grouped into two general categories: impressed current (ICCP) and galvanic.

Impressed current systems such as those that use **Ebonex®** discrete anodes and **Vectorode®** catalyzed titanium anodes utilize an outside power source. For long-term performance, these systems should be monitored and maintained. Ebonex anodes are ideal to protect heavily reinforced concrete, thick structural sections such as columns or beams, or steel framed masonry buildings while Vectrode anodes are placed into slots cut into the concrete surface or underneath a concrete overlay.

Galvanic systems are typically designed to provide corrosion control or cathodic protection. The systems are self-powered and require less monitoring and maintenance than ICCP. **Galvashield®** Jackets are used to protect marine pilings and other structures. **Galvanode® DAS** and **Galvanode® DAS Marine** anodes can also be used in concrete overlays, concrete jacketing and other concrete repair applications to provide long lasting galvanic protection.

Ebonex®

Galvanode® DAS Marine Anode

VECTOR CORROSION TECHNOLOGIES

CORROSION PROTECTION OPTIONS

Corrosion Passivation

Corrosion Passivation is provided by electrochemical treatments which are aimed at directly addressing the cause of the corrosion activity. **Norcure® Chloride Extraction** is used to address chloride contaminated structures such as bridges and parking garages. **Norcure® Re-alkalisation** is commonly used on carbonated building facades. These systems are installed onto the structure, operated for a short duration, then dismantled and removed leaving the structure in a passive condition. **Electrochemical treatments provide many of the long-term corrosion mitigation benefits of cathodic protection systems but without the need for maintenance and monitoring.**

Galvanic protection for patch repairs

A very common method of repairing spalled concrete due to chloride induced rebar corrosion, is reinstatement with low permeability repair mortars. This involves the removal of loose concrete and further breakout to clean the steel prior to mortar application.

However, this repair technique does not remove all chloride bearing concrete, which may remain in areas adjacent to the repair. Thus, new electrochemical corrosion cells may be set up between steel in the fresh repair (0% chloride) and the adjacent chloride contaminated concrete. This leads to premature failure at the periphery of a repair and is commonly referred to as the 'incipient anode effect'

The application of galvanic protection in this instance protects the periphery of the patch and provides Cathodic Prevention and therefore long-term stability to the repair. Galvanic systems are commonly used in this instance due to the 'install and walk away' performance.

This technique does not address the overall corrosion problem, but provides targeted protection to extend the life of repairs.

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CORROSION INVESTIGATION

Corrosion investigation

Cost-effective solutions are predicated on indentifying the cause of the problem, not just the symptom; therefore, a thorough evaluation of why the deterioration has occurred is recommended.

Investigating the extent and magnitude of corrosion provides useful information when designing a repair plan.

There are a wide range of assessment techniques available, including:

1. Visual assessments (cracking, spalling etc)
2. Analysis of the concrete (Carbonation Depths and Chloride Concentration)
3. Cover meter surveys (determine the distribution of the steel reinforcement)
4. Electrochemical surveys. (Half cell, Resistivity etc)

All of the above form an essential part of any assessment strategy, however, understanding the values obtained during such investigations is also important. The following tables provide summaries of what the results mean and how they may affect your structure.

These tables are for information purposes only and as with any such work, testing should be carried out by suitably qualified and independent bodies.

Half-cell testing

The half-cell test is generally used to give an indication of the condition of the steel reinforcement. The nature of this method means that it does not provide any information on the rate of deterioration.

T1. ASTM C876 criteria for interpretation of half-cell potentials

Potential of steel vs copper/copper sulphate reference electrodes	Possibility of corrosion
More positive than -200mV	Less than 10%
Between -200mV and -350mV	10-90%
More negative than -350 mV	More than 90%

Corrosion rate

This method of assessment provides information on the rate of corrosion where the reinforcement is no longer passive.

T2. Criteria for interpretation of corrosion current densities

Corrosion rate	Classification of risk
<0.1 to 0.2μA/cm^2	Passive
0.2 to 0.5μA/cm^2	Low to moderate
0.5 to 1.0μA/cm^2	Moderate to high
>1.0μA/cm^2	High

Concrete resistivity

Concrete resistivity is the measure of the ability of concrete to act as an electrolyte for the corrosion process. The values from such testing give an indication of the rate of corrosion and are normally used in conjunction with half-cell and chloride content data.

T3. Criteria for interpretation of resistivity measurements

Resistivity	Probability of risk
>100,000 Ωcm	Low corrosion rate probable
50,000-100,000 Ωcm	Moderate/low corrosion rate probable
10,000-50,000 Ωcm	High corrosion rate probable
<10,000 Ωcm	Very high corrosion rate probable

Chloride ion content

As we have seen throughout this document sufficient quantities of chloride in concrete initiates and catalyses steel corrosion. While this level of chloride required to initiate corrosion can vary considerable depending upon the concrete quality/type, general guidelines can be made.

These are provided in the table to the right.

T4. Criteria for interpretation of chloride ion contents within concrete

Chloride % by weight of cement	Risk of corrosion
<0.4	Negligible
0.4-1.0	Possible
1.0-2.0	Probable
>2.0	Certain

Galvashield® XP

SYSTEM DESCRIPTION	Disk shaped discrete anode - Alkali-activated zinc - 2G Technology
APPLICATIONS	Targeted Corrosion prevention for patch repairs and joints
PRODUCT DETAILS	Corrosion prevention spacing: 175 - 750mm

Galvashield® XPT

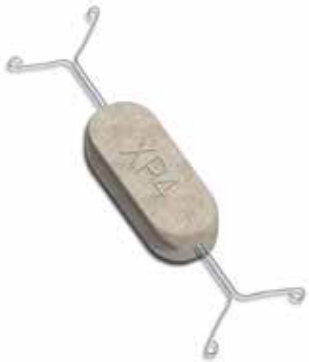
SYSTEM DESCRIPTION	Bar shaped discrete anode - Alkali-activated zinc - 2G Technology
APPLICATIONS	Targeted Corrosion prevention around patch repairs and joints. Low concrete cover or congested steel spacing
PRODUCT DETAILS	Corrosion prevention spacing: 175 - 750mm

Galvashield® XP2

SYSTEM DESCRIPTION	Oval shaped discrete anode - Alkali-activated zinc - 2G Technology - BarFit groove for secure anode placement
APPLICATIONS	Targeted Corrosion prevention or corrosion control for patch repairs and joints
PRODUCT DETAILS	Corrosion prevention spacing: 300 - 750mm Corrosion control spacing: 200 - 600mm

Galvashield® XP4

SYSTEM DESCRIPTION	Oval shaped discrete anode - Alkali-activated zinc - 2G Technology - BarFit groove for secure anode placement
APPLICATIONS	Targeted Corrosion prevention or corrosion control for patch repairs and joints. High chloride or high steel density structures
PRODUCT DETAILS	Corrosion control spacing: 150 - 750mm



GALVANIC SYSTEMS

Galvashield® N

SYSTEM DESCRIPTION	Bar shaped discrete anode - Extra long tie wires - Alkali - activated zinc - 2G Technology
APPLICATIONS	Corrosion prevention in new construction. Global protection and targeted protection around construction joints and other problematic areas
PRODUCT DETAILS	Corrosion Prevention spacing: up to 750mm

Galvashield® CC

SYSTEM DESCRIPTION	Cylindrical-shaped discrete anodes - Alkali-activated zinc - 2G Technology
APPLICATIONS	Corrosion control for concrete
PRODUCT DETAILS	Corrosion Control spacing: 325 - 700mm

Galvanode® DAS Marine

SYSTEM DESCRIPTION	Embedded mortar covered anodes for distributed protection - Alkali-activated zinc
APPLICATIONS	Galvanic encasements - Jacketing
PRODUCT DETAILS	Based on service life and protection requirements

Galvanode® DAS

SYSTEM DESCRIPTION	Embedded foil covered anodes for distributed protection - Alkali-activated zinc
APPLICATIONS	Galvanic encasements - Overlays
PRODUCT DETAILS	Based on service life and protection requirements

Galvashield® Jacket

SYSTEM DESCRIPTION	Galvanic anodes with a stay-in-place formwork - Distributed alkali-activated anodes or zinc mesh anodes - Bulk zinc anodes
APPLICATIONS	Galvanic encasements - Jacketing - Overlays. For marine or non-marine environments
PRODUCT DETAILS	Anode selection and spacing based on design requirements

VECTOR CORROSION TECHNOLOGIES

IMPRESSED CURRENT SYSTEMS

Ebonex®

SYSTEM DESCRIPTION	Cylindrical or star-shaped discrete anodes with high current capacity. Built-in ventilation - Crimps or electrical connectors
APPLICATIONS	Global or targeted protection - Reinforced concrete or masonary structures
PRODUCT DETAILS	Anode sizes: 7 to 28mm diameter lengths up to 600mm. Anode spacing based on design requirements

Vectrode® Anodes

SYSTEM DESCRIPTION	Range of MMO Titanium anodes and related components
APPLICATIONS	Global or targeted protection - Reinforced concrete, masonary, or buried structures
PRODUCT DETAILS	Mesh, Tibbon Mesh, Tubes, Wire

ELECTROCHEMICAL TREATMENTS

Norcure® Chloride Extraction

SYSTEM DESCRIPTION	Long term corrosion passivation with short term electrical treatment. Reduces chloride and increases pH around reinforcing steel
APPLICATIONS	Chloride contaminated concrete - Large area treatment
PRODUCT DETAILS	4 to 8 week treatment time - Barrier protection recommended if re-exposed to chloride

Norcure® Re-Alkalisation

SYSTEM DESCRIPTION	Long term corrosion passivation with short term electrical treatment. Potassium or sodium carbonate used as electrolyte
APPLICATIONS	Carbonated concrete - Large area treatment
PRODUCT DETAILS	2 to 8 week treatment time - Will not re-carbonate

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CORROSION MITIGATION COMPARISON CHART

	PRODUCT	LEVEL OF PROTECTION	SERVICE LIFE	ANODE SIZE
GALVANIC TREATMENTS	Galvashield XP	Pr	10 - 20 Years	65 x 30mm (2.5” x 1.2”) 60 grams of zinc
	Galvashield XPT	Pr	10 - 20 Years	25 x 125 x 25mm (1” x 5” x 1”) 60 grams of zinc
	Galvashield XP2	Pr CC	10 - 20 Years	65 x 80 x 30mm (2.5” x 3.1 x 1”) 100 grams of zinc
	Galvashield XP4	Pr CC	10 - 20 Years	65 x 120 x 30mm (2.5” x 4.7” x 1”) 160 grams of zinc
	Galvashield N	Pr	10 - 20 Years	25 x 125 x 25mm (1” x 5” x 1”) 60 grams of zinc
	Galvashield CC	Pr CC	10 - 20 Years	CC65, CC100, CC135
	Galvanode DAS	Pr CC CP	10 - 40 Years	Zinc mass:0.25, 0.6, 1.2, 2.0 lb./ft. (0.37, 0.89, 1.8, 3.0 kg/m)
	Galvanode Jacket	Pr CC CP	10 - 40 Years	Distributed alkali-activated or zinc mesh, bulk zinc anode
ICCP	Ebonex	CP	25 + Years	7 - 28mm diameter, lengths up to 600mm
TREATMENTS	Norecure Chloride Extraction	Pa	20 + Years	Varies
	Norecure Re-Alkalisation	Pa	Indefinite	Varies

LEVELS OF PROTECTION

Pr - Corrosion Prevention

Used to prevent corrosion activity from initiating in contaminated concrete. If concrete repair projects are completed in accordance with industry guidelines, the replacement of damaged concrete will address the areas with the highest level of corrosion activity. But after the repairs are complete, new corrosion sites are likely to form in the remaining contaminated concrete which was passive before the repairs. Research in the area of corrosion prevention indicates that a low applied current density (in the order of 0.4 mA/m2 of steel surface area) is effective at preventing the initiation of corrosion in concrete. The required current will decrease over time as chemical reactions increase the alkalinity and decrease the concentration of chloride ions around the reinforcing steel.

CC - Corrosion Control

Utilized when active corrosion exists. The use of corrosion control systems will provide a reduction in the corrosion rate and increases the service life of the rehabilitated structure. In many cases, this level of protection can be provided with low incremental cost as the protection can be targeted at specific areas of contamination or corrosion activity. The current requirements for corrosion control are higher than for corrosion prevention, generally in the range of 1 to 7 mA/m2 and can decrease over time as the beneficial effects of chemical reactions build up the alkalinity and decrease chloride concentrations around the reinforcing steel.

VECTOR® CORROSION TECHNOLOGIES

ANODE TYPE	APPLICATIONS	SPECIAL FEATURES	MITIGATION STRATEGY
Discrete Embedded	Patch and joint repair, interfaces between new and old concrete	2G Technology	L
Discrete Embedded	Same as Galvashield XP, low concrete cover, tight spaces	2G Technology	L
Discrete Embedded	Wider spacing than Galvashield XP, higher current density for corrosion control	2G Technology, BarFit groove	L
Discrete Embedded	Wider spacing than Galvashield XP2, higher chloride corrosion control	2G Technology, BarFit groove	L
Discrete Embedded	New construction, large areas or target high risk areas, e.g control joints	2G Technology, Extra long lead wires	L, G
Discrete Embedded	Protection of areas with active corrosion, embedded into drilled holes	2G Technology, quick rebar and anode connection devices	L, G
Distributed Embedded	Galvanic encasements of reinforced concrete, pile jacketing, overlays, large area repairs	Custom sizes avaliable	L, G
Distributed Embedded	Marine or non-marine piles and columns	Stay-in-place formwork	G
Discrete Embedded	High current capacity, reinforced concrete beams and columns, steel frame masonary buildings	Vented, special connectors, acid resistant grout	L, G
Distributed, Temporary Surface Applied	Chloride contaminated beams, archs, columns and other large areas, historic structures	Does not significantly change structure appearance	G
Distributed, Temporary Surface Applied	Widespread carbonation, historic structures	Does not significantly change structure appearance	G

CP - Cathodic Protection

Provides active long term protection. Cathodic protection should be selected when the highest level of protection is necessary and the cost is economically justified. Current industry standards for cathodic protection are based upon a 100 mV depolarization acceptance criteria. This level of protection generally requires an initial operating current between 5 and 20 mA/m2. Current may be provided by galvanic anodes or by an impressed current power supply. Impressed current systems should be monitored and maintained over time.

Pa - Corrosive Passivation

Achieved by changing the environment around the steel to a significantly less corrosive condition. This can be achieved by reducing the amount of chloride or by increasing the pH around the steel by using a temporary electric field. The systems are installed until the objective is achieved then removed so that no firther monitoring or maintenance is required.

Special Features

2G Technology - Includes special additive for increased anode current.

BarFit - Grooved design or plastic spacers for secure fit to steel.

L-Local - A local corrosion mitigation strategy is utilized when only targeted areas require protection or if global protection is outside the owner's current budget.

G-Global - A Global corrosion mitigation strategy is utilized when protection is required for an entire structure or large structural elements.

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VECTOR CORROSION TECHNOLOGIES

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