Understanding Corrosion

Environmental factors and protective measures for structural steel

For the protection of concrete and steel structures through condition assessment, testing and inspection of concrete repair, corrosion control, and protective coating systems.

REMEDY ASSET PROTECTION
CORROSION CONSULTANTS FOR CONCRETE REPAIR AND STEEL PROTECTION

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Introduction

According to research by the Curtin University of Technology, corrosion may be costing the Australian economy more than $30 billion each year, much of which is preventable.[1] Corrosion, which refers to the irreversible degradation or destruction of steel due to a reaction with its environment, is a significant problem across all industries but is of special concern in high-value buildings and infrastructure. If left unchecked, it can lead to property damage, high remediation costs and, in the worst cases, structural failure.

To protect their investments in the long term, asset owners and managers need to consider strategies to prevent corrosion of structural elements in their buildings. Across the country, effective management and prevention of corrosion could save $8 billion each year.[2] This raises the question as to what mistakes in corrosion management need to be avoided and what measures should be adopted to protect building assets over their lifetime.

As those responsible for design and choosing suitable building materials, architects and specifiers play a critical role – they must ensure corrosion vulnerability across the entire building is fully evaluated and addressed so they can deliver buildings that last. A strong understanding of how corrosion occurs and the contributing factors will provide opportunities to minimise or remove the risk of corrosion during the design stage of a project.

In this whitepaper, we help designers and specifiers understand the impact of corrosion on building structures. We also consider how different environmental conditions affect corrosion rates, and how this impacts the selection of corrosion prevention and management strategies.

Corrosion and the built environment

Corrosion is the gradual destruction of metals due to natural processes, commonly through oxidation. When metals are exposed to the environment, particularly acids, moisture and oxygen, those actions instigate chemical reactions that change the properties of the material, wearing it away and/or reducing its strength. One of the most common forms of corrosion is rust, a term reserved for iron and steel, which is caused by an electro-chemical reaction due to contact with moisture or polluted air.

Due to its low cost and many desirable properties for architectural applications, steel is one of the most common metals used in buildings. Accordingly, metallic corrosion is a major issue in building design and construction. The structural effects of corrosion include loss of mechanical strength and structural damage, fatigue and cracking, weakening of structural bonds (e.g. between steel and concrete) and reduced seismic performance.

Corrosion affects all reinforced concrete buildings and structures to some extent. Rust can not only affect a building's appearance, but it can also be hazardous to human health and safety. When rust occurs unchecked, it can degrade an asset to the point of failure. In the worst-case scenario, the integrity of the building structure is compromised, resulting in the need for partial or complete demolition. Furthermore, corrosion can reduce the value of a building, making it a special concern for asset owners and other stakeholders.

Addressing metallic corrosion issues can come at a high cost, yet such damage is often the result of simple mistakes: substandard materials, poor workmanship, poor knowledge or insufficient attention to corrosion protection of an asset during the design phase. Failure to observe and adhere to design standards and a lack of good coating applications can lead to premature maintenance and corrosion problems that occur earlier than expected in the building's lifespan.

Corrosion damaged electrical cabinet.

Sustainability

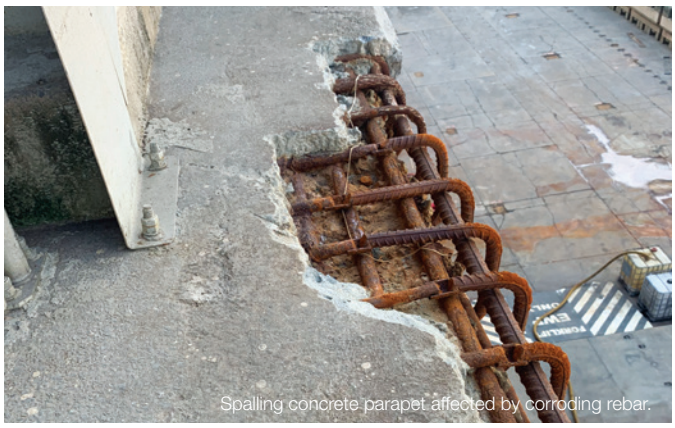
Corrosion has a massive effect on sustainability through all aspects of construction – from expensive remediation, costly maintenance, loss of structural integrity, through to reduced building life. Accordingly, architects, designers and builders can improve environmental and societal outcomes by effectively managing corrosion.

Managing corrosion directly contributes to better sustainability outcomes through reduced maintenance and by increasing the service life of the building. The longevity and durability of a building is a key aspect of sustainable design. A building that lasts for a long time enables the environmental costs of its construction to be amortised over many years. The longer a building or any of its components last, the less materials, energy and resources are needed to repair or replace it. There is also greater potential to reuse the building's materials and components after its initial service life. An example is the many industrial warehouses converted into residential apartments.

The right corrosion protection and management measures can not only increase a building's longevity by preventing the potentially devasting impacts of corrosion, but also reduce maintenance requirements over the building's lifespan. Durability and longevity often go hand-in-hand with low maintenance – the easier a building is to maintain, the more likely the owner will successfully do so over a long period of time. Structures that require regular maintenance, replacement or repair consume more materials, energy and resources over their service life.

Where does corrosion happen in a building?

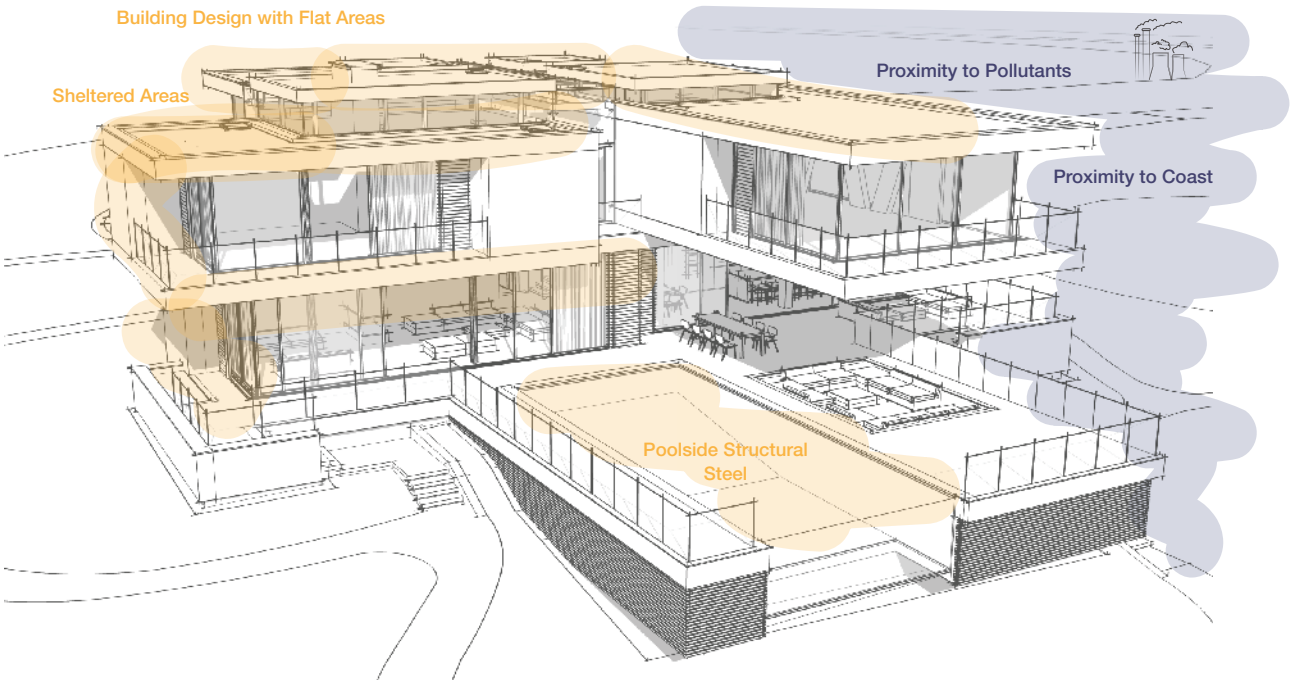
- **Exterior.** Metal that is used on the exterior of buildings are subject to atmospheric conditions that can cause corrosion. The principal factors that affect metallic corrosion on a building's exterior are temperature, weather, pollution, atmospheric salinity and the length of time during which metal remains wet by water.
- **Interior.** While protected to some extent from external weather elements by cladding and roofing, metals within the building structure can still corrode from prolonged exposure to moisture. This exposure can occur from rain penetrating the building exterior or condensation of water vapour.
- **Concrete and masonry.** There are many examples of corrosion in metal components encased in concrete and masonry. This occurs due to poor quality concrete and masonry and/or poor design – the concrete may contain too much moisture or have high water permeability.
- **Building services.** Corrosion can occur on metal components in building services such as heating, water supply and sewage disposal systems, due to exposure to moisture, steam and corrosive chemicals.
- **In ground.** Metals buried in soil can be subject to severe corrosion issues arising as a result of the presence of certain soil bacteria. This type of corrosion is often of a different nature to atmospheric corrosion, and requires specialist advice to determine the appropriate prevention methods.



Spalling concrete parapet affected by corroding rebar.

Corrosion damaged structural steel post encased in concrete.

ATMOSPHERIC CORROSION: MACRO-ENVIRONMENTS VS MICRO-ENVIRONMENTS



Macro-environment: The environment generated by normal weather patterns and atmospheric conditions in a specific area.
Micro-environment: Small-scale environments modified by local building features.

Risk of corrosion in different environmental conditions

CORROSIVITY ZONES

In typical atmospheric conditions, the rate of corrosion is generally well understood. Coastal areas and marine environments have a higher risk of corrosion than properties located inland due to the presence of sea salt in the atmosphere. Building exteriors are vulnerable as they are subject to the outside environment, especially if the location is subject to consistent rain and/or salt deposits.

The higher risk of corrosion in such environments is reflected in the categorisation of corrosivity zones in AS 4312:2019 “Atmospheric corrosivity zones in Australia”. Under this Standard, corrosivity zones are generally defined in relation to proximity to the ocean and the severity of coastal conditions. The corrosovity zones are divided into six categories:

CATEGORY	CORROSIVITY
C1 Dry Indoors	Very low
C2 Arid/Urban Inland	Low
C3 Coastal	Medium
C4 Calm Sea-shore	High
C5 Surf Sea-shore	Very high
CX Severe surf shore-line	Extreme

THE EFFECT OF MICRO-ENVIRONMENTS

Corrosivity rates of steel can be significantly changed by micro-environments in and around a building. Several micro-environmental factors that impact material performance are expanded upon below.[3]

SEVERITY OF THE ATMOSPHERIC ENVIRONMENT

When assessing corrosion vulnerabilities, it is important to consider the specific environmental and atmospheric conditions of the building location. Rural, marine, industrial and geothermal sites have specific characteristics that may impact corrosion rates, and no two sites are exactly the same in this regard. Airborne salinity and sulfur dioxide content are both key contributors to corrosion, and their deposition rates on non-sheltered surfaces are typically proportionate to their concentration in the atmosphere.

Certain environmental variables, such as, prevailing wind directions, amount of rain, speed of rain, temperature, and humidity, can have different impacts depending on the environment. For example, rainfall can stimulate corrosion in some environments, but may serve to wash away corrosive pollutants from steel surfaces in other environments.[4] In some cases, increased temperatures may accelerate corrosive reactions, but may also help dry the surface of the material faster, which can decrease corrosion rates.

TYPE AND CONCENTRATION OF POLLUTANTS

The presence of different types of pollutants can also modify corrosion rates to a significant degree. For example, airborne industrial chemicals and solvents can cause very high corrosion rates and deteriorate protective coatings, especially if the structure is located close to the source of the pollution. This is supported by testing, which has shown higher corrosion rates in chemical plant atmospheres when compared to non-polluted areas away from the coast.[5] If allowed to build up, dust and other inert materials can also increase corrosion rates.[6]

DESIGN FEATURES OF THE BUILDING

The geometry, orientation and configuration of surfaces and materials can vary widely from building to building. Surfaces can be mounted in all directions, vertically, horizontally and at different angles. Surfaces can be oriented differently in relation to the sun or the general direction of rainfall. Areas of a building may be enclosed and protected from the outside environment, but some specific interior conditions (e.g. damp, contaminated environments) may be more conducive to corrosion than others.

There is a complex relationship between these design elements and the atmospheric conditions of the site. All these factors can impact ‘time of wetness’,[7] referring to how a long a surface is covered by a film of water that makes corrosion possible. How long a metal surface remains wet is influenced by not only atmospheric conditions, but factors such as the slope of the surface, its exposure to sunlight, sheltering and shading, effectiveness of drainage and so on.

Failure to observe and adhere to design standards and a lack of good coating applications can lead to premature maintenance and corrosion problems that occur earlier than expected in the building’s lifespan.

When do you need a corrosion expert?

When specifying measures to protect steel from corrosion, architects and structural engineers tend to refer closely to the National Construction Code (NCC) and the relevant standards, such as AS/NZS 2312:2002 “Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings”.

While the effects of micro-environments on the corrosivity rates of steel are acknowledged in Australian standards, they do not cover all real-life situations. It is possible to specify inferior coating systems that are technically compliant, but do not accurately account for the wide range of micro-environments contributing to corrosivity rates on the site.

It is difficult predicting how structures will behave in the real world, which is why it is important to engage with a corrosion expert to assess vulnerabilities and help determine the appropriate protection strategies. Below are three examples where it is recommended to engage with a corrosion expert to develop a robust corrosion prevention and management system.

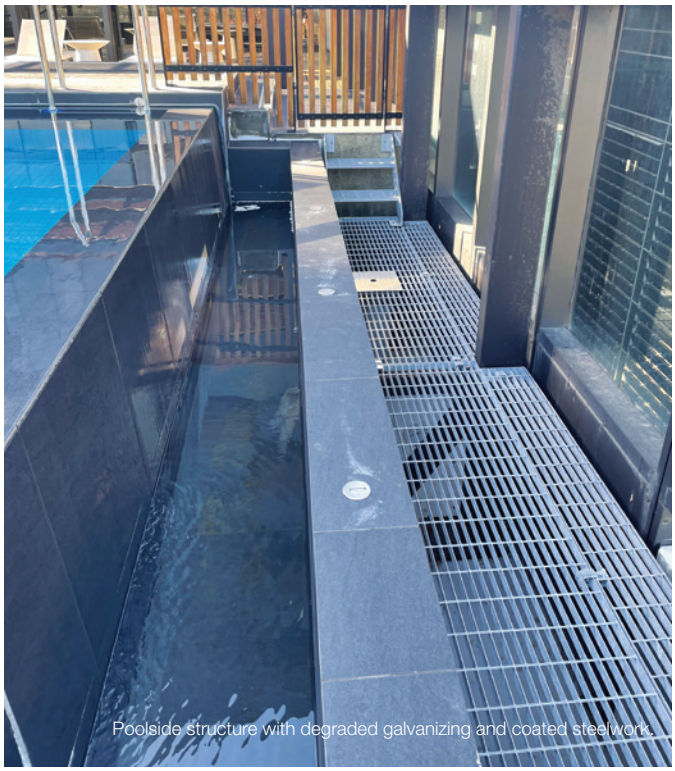
WITHIN 1KM OF COASTLINE

Corrosion protection requirements are most stringent for structures built within 1km of the coast primarily due to the effects of sea salt spray on the building exterior. The NCC requires robust corrosion protection measures for buildings constructed within 1km of breaking surf, and other similar exposure environments.

The use of specially treated or higher-grade products will vary depending on how close to salt water the structure is built. Corrosion protection strategies include powder coatings to aluminium door and window frames, the use of marine-grade stainless steel, hot-dip galvanized structural steel and galvanized tie-down rods and fixings. Selection of the most effective prevention methods will require specialist input.

POOLSIDE STRUCTURES

Swimming pool areas are damp, corrosive environments requiring steelwork and other structural elements to be appropriately protected. Chlorine and other high acid gases can accelerate steel corrosion. Poolside structures can also be affected by algae and mould, which can create destructive compounds and acids that degrade steel. Both galvanization and architectural coatings can help however chlorine quickly wears the protection away. Protective coatings are required to effectively mitigate corrosion issues. In indoor pool enclosures, ventilation of harmful chemicals to the outside can help reduce corrosivity.



Poolside structure with degraded galvanizing and coated steelwork.

SHADED AREAS

Sheltered surfaces in some environments corrode faster as they are protected from cleansing rain that can wash away salt deposits. Placing unprotected steel in sheltered or continuously damp or shaded areas will typically result in rapid deterioration of the steel structure.

Under balcony area provided early onset corrosion of structural steel.

What about maintenance?

A robust maintenance program is needed to manage corrosion risks over the long term and ensure longevity of a structure. In some scenarios, simply cleaning and washing the structure regularly can significantly reduce the risk of corrosion. For more complex structures, maintenance includes preventative action, such as inspecting, monitoring and correcting potential corrosion issues, and corrective action to address design defects that may interfere with the effectiveness of protective coatings or restore degraded steelwork.

Inspection of protective coatings to structural steel work during erection.

PROTECT YOUR ASSETS WITH CORRASSURE™

In order to achieve suitable corrosion protection, it is important to understand the requirements of the project environment and have clear and appropriate coating specifications and a robust maintenance program. These systems of procedures are needed as corrosion is not always properly addressed in mandatory codes and standards.

A leading provider of coating inspection services and corrosion assessments for industrial and commercial paint and concrete coatings projects, RemedyAP have taken the durability lessons learned in heavy industry and packaged them into CorrAssure™ – a set of systems and procedures to help protect everyone in the supply chain from the early onset of corrosion.

To enable the effective management of corrosion in building projects, CorrAssure™ for the Construction Industry encompasses broad-ranging corrosion protection services for all project stakeholders, including:

- Design and specification review – to include items requiring more robust control measures.
- Inspection – during building phases to capture any improvements required to minimise corrosion problems.
- Certification – where recommendations have been reviewed and implemented, RemedyAP will provide a Certificate of Assurance that the observed corrosion protection systems will provide minimum 5-year corrosion resistance to local atmospheric conditions.

Managing corrosion directly contributes to better sustainability outcomes through reduced maintenance and by increasing the service life of the building.

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All information provided correct as of February 2022

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