

# Guide to the Durability of Hot Dip Galvanized Steel

Issue 4.0 | September 2025



No coating has proven to be more durable and of such predictable performance in the Australian and New Zealand atmosphere for protecting steel than hot dip galvanizing.

*Cover page: The Austin Hospital car park extension which used approximately 1500 tonnes of hot dip galvanized steel.*

|                                                                                                                     |    |
|---------------------------------------------------------------------------------------------------------------------|----|
| Introduction                                                                                                        | 1  |
| Key factors affecting the durability of metals in the atmosphere                                                    | 1  |
| Airborne sea salts                                                                                                  | 2  |
| Surface wetness                                                                                                     | 2  |
| Localised industrial pollution                                                                                      | 2  |
| Climate Change                                                                                                      | 3  |
| Protective life of galvanized coating                                                                               | 4  |
| Estimation Methods                                                                                                  | 4  |
| Factors of corrosivity in different environments                                                                    | 5  |
| How service life relates to coating thickness                                                                       | 8  |
| Estimating the durability of hot dip galvanized and zinc coatings using the first-year corrosion rate from ISO 9223 | 9  |
| Estimating the durability of hot dip galvanized and zinc coatings for steady-state corrosion using ISO 9224         | 11 |
| Corrosion charts                                                                                                    | 14 |
| How to read the charts                                                                                              | 14 |
| Galvanized reinforcing steel                                                                                        | 15 |
| Effect of temperature                                                                                               | 15 |
| Under water                                                                                                         | 16 |
| Embedded in soil                                                                                                    | 17 |
| In contact with chemicals                                                                                           | 18 |
| Sewage treatment                                                                                                    | 19 |
| Transport and storage                                                                                               | 19 |
| Bimetallic corrosion                                                                                                | 20 |
| Galvanized surfaces in contact with other metals                                                                    | 20 |
| Galvanized coatings for buildings and structural steel                                                              | 21 |
| In contact with building materials                                                                                  | 21 |
| Posts embedded in concrete                                                                                          | 21 |
| In contact with timber                                                                                              | 21 |
| Lintels                                                                                                             | 22 |
| Duplex systems – Paint over galvanizing                                                                             | 23 |
| Bibliography                                                                                                        | 24 |

## Introduction

Hot dip galvanizing has consistently proven to be the most durable and reliable coating for protecting steel in the Australian and New Zealand environments. The excellent performance of galvanized coatings in atmospheric and various other exposure conditions is primarily due to the formation of a protective patina. Once stabilized, this patina—composed of insoluble zinc oxides, hydroxides, and carbonates depending on the environment—significantly slows further reaction, resulting in extended coating life. In the Australian and New Zealand climates, galvanizing also benefits from its resistance to the damaging effects of solar radiation. For this reason, in terms of durability alone, galvanizing is likely to significantly outperform organic coatings under such conditions.

Even in humid and coastal climates, the corrosion rate of hot dip galvanized steel is very low compared with that of uncoated steel (Table 1). In addition, it is a robust coating, highly resistant to wear and impact during transport, installation and service. While organic coatings tend to shrink from sharp corners and can be difficult to apply to complex shapes, galvanizing ensures an essentially even coating over all surfaces accessed by the molten zinc. Importantly, it protects the steel substrate until the zinc has corroded away — unlike paints, where corrosion of the steel can progress unnoticed under the paint film.

## Key factors affecting the durability of metals in the atmosphere

In most cases, when estimating the expected service life of a steel fabrication and its coating, we refer to the macro- and micro-environmental influences. Figure 1 shows the multiscale model of corrosion developed by Cole, which notes the prevailing corrosive influences at each scale.

The location of the article relative to the corrosive influences is particularly important. For example, a steel fabrication in an air-conditioned office building is unlikely to suffer any significant corrosion, while one on the outside of the same office building will be exposed to corrosive influences such as condensation, rainfall, pollution and airborne salts, affecting the service life of the coating. Similarly, the structure of an open sided carport near the coast is normally subject to more corrosive influences than a fully enclosed shed.

The nature of corrosion of steel and zinc coatings is well understood, with multiple research and long-term test sites used to develop corrosion Standards suitable for Australia and New Zealand and to estimate the corrosion rate of coatings and structural steel in atmospheric conditions. Over the past 5 to 10 years, the GAA has carried out long-term testing at a marine (C5) site, studying how micro-environmental factors such as sheltering and shielding affect galvanized and other coatings in relation to the broader macro-environment.



*A pole from the famous Morse Code lines installed from Charters Towers to Thursday Island, dating from around 1886 with cross-rails added in 1942, and abandoned in-situ when overtaken by new technology.*



*Many of the Morse Code line poles are still standing or have been recently recovered with near original coating thicknesses now at least 130 years on in a variety of severe exposure.*



*Galvanized guard rails have a good record of performance along the Great Ocean Road in Victoria.*

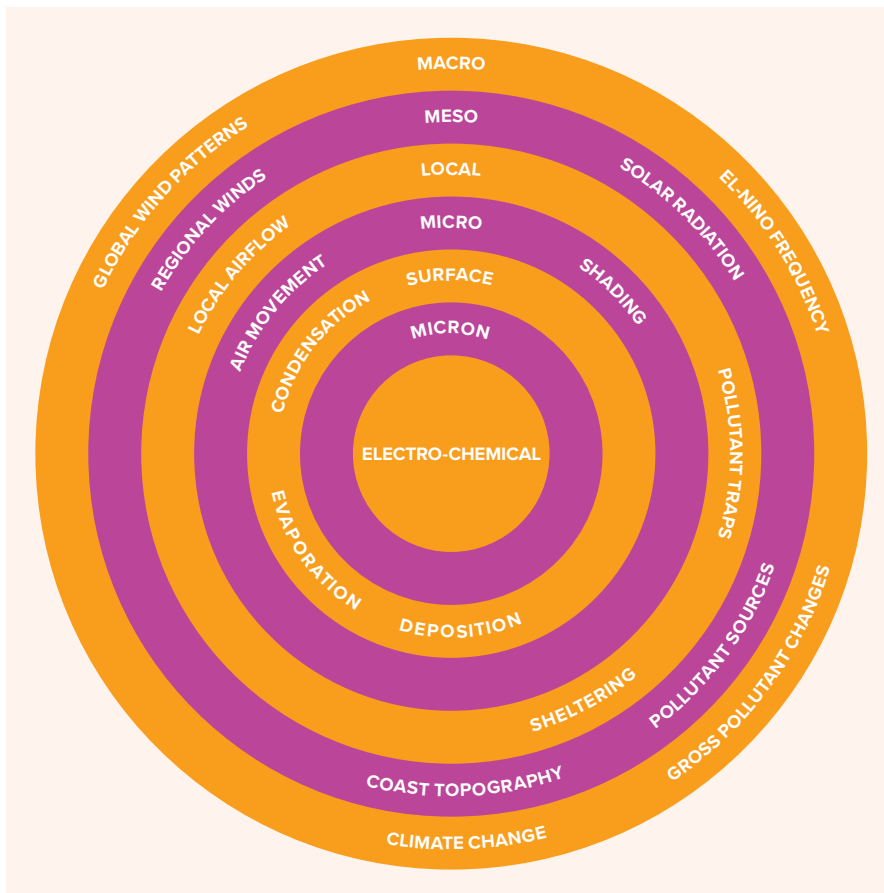


Figure 1 Definition of the scale domains for the holistic model of corrosion

## Airborne sea salts

Extensive research in Australia, New Zealand, and internationally has shown that the corrosivity of the atmosphere is very much related to the proximity of the coast, the frequency of onshore prevailing winds, topography and the presence of sheltered, unwashed surfaces.

The natural cleansing action of rainwater washes most contaminants off a galvanized surface where they might otherwise accelerate corrosion. In coastal environments, corrosion rates in sheltered areas can be higher than those on exposed surfaces of the same article. Examples are surfaces sheltered from sun and wind and prone to long term condensation, and surfaces sheltered from rain and exposed to onshore winds.

## Surface wetness

Atmospheric corrosion can only occur in the presence of an electrolyte, and the longer a hot dip galvanized surface remains wet (known as time-of-wetness), the more quickly it will corrode. Therefore dew, rainfall, melting snow, and a high humidity level will all influence the rate of corrosion. Also important is the orientation of the surface-(including slope) and the potential for crevices and laps to hold water, as these factors may create an environment conducive to localised corrosion.

If a surface is exposed to airborne sea salts and subject to dew, but protected from rainfall, the corrosion rate will be significantly accelerated compared to the same surface that is frequently cleansed by rain events. In contrast, when humidity levels are below 60% (for example, in an air-conditioned building), corrosion rates are very low and can often be ignored.

## Localised industrial pollution

The impact of industrial activities on hot dip galvanized steel in Australia and New Zealand is usually insignificant. This is because of the low concentration of industrial activity in most regions and the marked reduction in the use of sulfur bearing fuels over the last 50 years, particularly during the early 1970's when environmental protection was strengthened by government legislation. This change mirrors those throughout the developed world due to increasing industry responsibility, particularly of the reduction of air pollution by sulfur dioxide.

In Australia the main sources of industrial sulfur dioxide production are electricity generation from coal, oil or gas and processing of metal and mineral sulfide ores, while in New Zealand the production of fertiliser and other industrial processes and the combustion of heavy fuel oil used in maritime vessels also contributes to production of sulfur dioxide. Geothermal and volcanic gases are natural sources of sulphur dioxide in New Zealand.



Galvanized conveyor frames are used successfully in the iron-ore mining industry

Long-term results of air monitoring in both Australia and New Zealand have shown that levels of pollution continue to decline in most locations. References to these results are contained in the Bibliography.

Other kinds of pollution can also increase the rate of corrosion; for example, nitrous oxides, nitric acid and industrial dust in populated and industrial zones or the specific operational and technological pollution of microclimates; for example, chlorine, hydrogen sulphide, and organic acids. These types of pollution require expert analysis to determine their effect on corrosivity but are generally confined to specific applications and can be ignored when assessing general atmospheric corrosion.

In general, industrial pollution is no longer a significant influence on the durability of hot dip galvanized steel in Australia and New Zealand. Local environments should be considered on a case-by-case basis.

## Climate Change

Research suggests that an increase in the earth's surface temperature is unlikely to have a significant adverse effect on corrosion, however changes in relative humidity, wind patterns, cloud cover, the increasing frequency of severe events and the reduction in frequency of smaller rainfall events, combined with reduced time of wetness are all expected to result in long-term effects on the corrosion of structural steels in our region.

The most prominent effect of climate change may be the effect that reduced frequency of rain events will have on surface cleaning. In coastal zones within 50 km of the coast, this could increase corrosion rates by up to 100% for a surface that would normally be cleaned by rain. In contrast, for inland areas, a reduction in relative humidity could dramatically affect the time-of-wetness on a surface, as the effect is very dependent on the exact diurnal relative humidity cycle, and for certain diurnal cycles time-of-wetness could significantly decrease. If time-of-wetness does decrease, the corrosion rate would be expected to decrease accordingly. Conversely, in tropical regions a decrease in humidity may see airborne salts travel further inland which will increase corrosivity accordingly.

Climate estimates for 1990 and 2100 have been used to show that one possible outcome of the above opposing tendencies is a decrease in the relative corrosion rate of zinc of approximately 9% for Melbourne (southern Australia) and an increase of approximately 14% for Brisbane (northern Australia). These possible variations highlight that long-term corrosion estimates for hot dip galvanized structural steel require detailed analysis of all key influencing factors and carry an inherent level of uncertainty. They also emphasize the importance of climate change data collection for effective long-term planning.



*The Cairns Institute uses hot dip galvanized steel as a fabricated lattice facade.*

## Protective life of galvanized coating

### Estimation Methods

There are two methods available for designers and specifiers to estimate the durability of hot dip galvanized coatings. These are by using:

1. The **first-year** corrosion rate of zinc from ISO 9223, *Corrosion of metals and alloys – Corrosivity of atmospheres – Classification, determination and estimation*
2. The **long-term steady state** corrosion of zinc from ISO 9224, *Corrosion of metals and alloys – Corrosivity of atmospheres – Guiding values for the corrosivity categories*

**ISO 9223** uses the general term Corrosivity Category to broadly describe the corrosion rates of steel, zinc, copper and aluminium in various atmospheric conditions based on world-wide historical knowledge and test results. Table 1 provides the first-year corrosion rates for steel and zinc in the six Corrosivity Categories defined by ISO 9223. In Australia (AS 4312) and New Zealand (SNZ TS 3404), detailed location descriptions of these general categories are provided for engineering estimation purposes. This Guide also provides typical and specific examples of locations for each corrosivity category in Table 2 and Table 3 for Australia and New Zealand, respectively. ISO 9223 is useful as it provides first-year corrosion rates for the corrosivity categories, allowing for easy and conservative estimates for durability. Simply, if the ISO 9223 estimation method provides the required durability for a structure, then significant extra work is unlikely to be required, unless consideration of an alternative coating thickness or steel thickness is desired.

**ISO 9224** provides guiding values of corrosion in atmospheric conditions which can then be used to predict the long-term durability of galvanized coatings based on measurements or estimates of corrosion of the hot dip galvanized coating in the first-year exposure. The guiding values in ISO 9224 are based on many exposures in many locations throughout the world, but they do not cover all situations in all natural environments and service conditions, particularly where significant changes in the environment can cause major increases or decreases in corrosion rates. If you plan to use ISO 9224 for design, GAA and GANZ recommends consulting with qualified experts, especially where local corrosion (micro-environment) is more important than general corrosion (macro-environment). Local corrosion includes galvanic (bimetallic), pitting and

crevice corrosion, while other micro-environmental corrosion effects such as from unwashed surfaces can often be estimated from first-year data.

In summary, ISO 9223 data, presented as a range of durability in years within AS/NZS 2312.2 provides the most conservative prediction for the rate of corrosion of hot dip galvanized coatings in Australia and New Zealand and is best used for initial assumptions. Durability for a range of common coatings using the ISO 9223 method is shown in Table 4. ISO 9224 provides corrosion prediction models expressed as formulae. These have been used to generate the data presented in Table 6 of this Guide. This information is particularly useful for long-term corrosion estimates, especially where macro-environmental conditions dominate over local micro-environmental effects.

**Table 1: first-year Corrosion rates of steel & zinc**

| Category, description & typical environment |           |                       | ISO 9223 corrosion rate for the first year (µm/y) |              |
|---------------------------------------------|-----------|-----------------------|---------------------------------------------------|--------------|
|                                             |           |                       | Mild steel                                        | Zinc         |
| <b>C1</b>                                   | Very low  | Dry indoors           | ≤1.3                                              | ≤0.1         |
| <b>C2</b>                                   | Low       | Arid/Urban inland     | >1.3 to ≤25                                       | >0.1 to ≤0.7 |
| <b>C3</b>                                   | Medium    | Coastal or industrial | >25 to ≤50                                        | >0.7 to ≤2.1 |
| <b>C4</b>                                   | High      | Calm sea shore        | >50 to ≤80                                        | >2.1 to ≤4.2 |
| <b>C5</b>                                   | Very High | Surf sea shore        | >80 to ≤200                                       | >4.2 to ≤8.4 |
| <b>CX</b>                                   | Extreme   | Ocean/Off-shore       | >200 to ≤700                                      | >8.4 to ≤25  |



*This galvanized steel test piece has had circular areas of the coating removed before exposure in a severe industrial environment. Sacrificial protection provided by the surrounding zinc coating has prevented corrosion of circles up to 3mm diameter and minimised corrosion of 5mm circle. Larger circles also exhibit corrosion-free annular areas adjacent to the surrounding coating.*



*This gas processing facility in the NT is in a C3 coastal zone.*

## Factors of corrosivity in different environments

In warm dry atmospheres zinc is very stable. The patina formed during initial exposure remains intact, preventing further reaction between the galvanized coating and the air, and protection continues indefinitely. This is typical of internal air-conditioned environments and most residential houses. The corrosion rate of zinc in these atmospheres is very low and most commercially available galvanized coatings will provide a protective life of over 100 years.

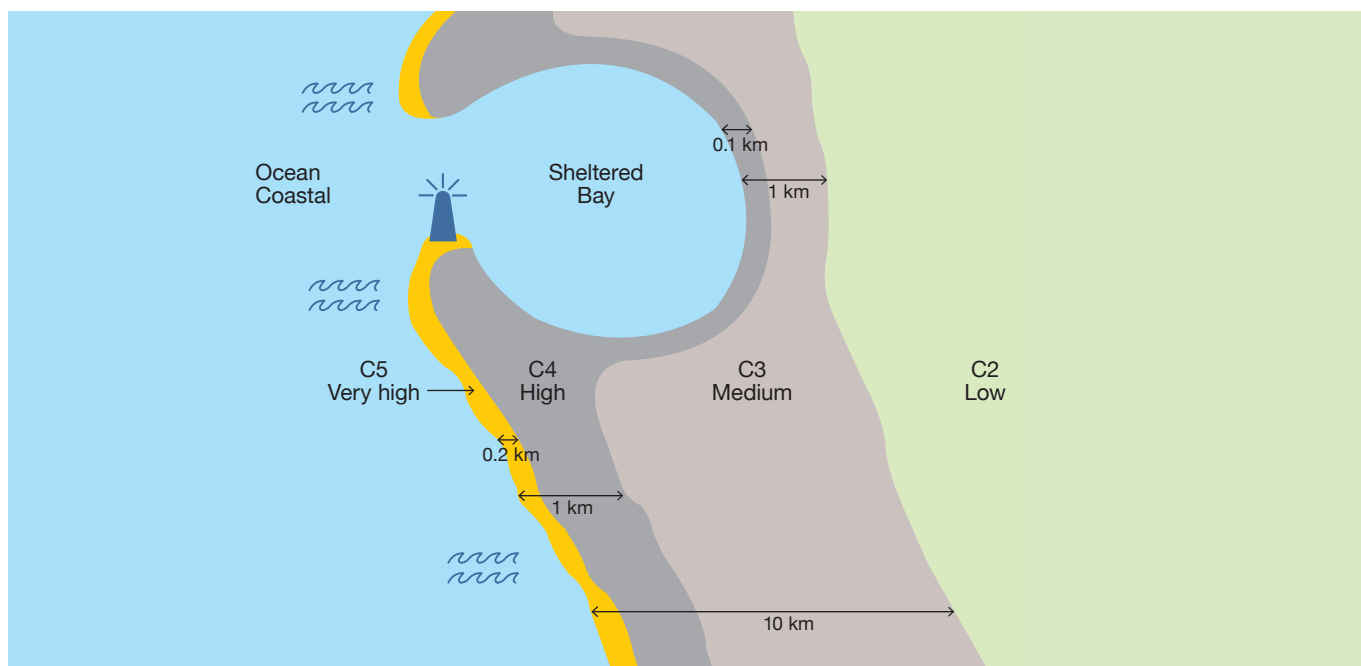
In the presence of atmospheric moisture, zinc oxide rapidly converts to zinc hydroxide, which then reacts with carbon dioxide in the air to form basic zinc salts like zinc hydroxy carbonate. These stable, inert compounds inhibit further corrosion and contribute to the long-term durability of the galvanized coating.

In rural areas and parts of major cities, galvanized coatings can often last over 100 years, though their lifespan may be reduced by micro-environments that increase surface wetness duration or exposure to airborne contaminants.

In dry form, some fertilizers, including those containing ammonium nitrate, are extremely hygroscopic and readily absorb atmospheric moisture which then increases the corrosion rate. Other fertilizers and insecticides in dry form may be harmless to zinc coatings but when wetted by rainwater or irrigation spray water, aggressive solutions can be formed which will attack galvanized coatings until washed off by further wetting. Intensive animal farming generates an aggressive micro-environment due the presence of sulfur and ammonium compounds generated by animal waste. Similarly, exposure to chemical pollutants can increase the local corrosion rate.

Both the corrosion mechanism and corrosion rate of zinc in soil differs to atmospheric corrosion in the same location, so alternative methods must be used to estimate durability. However, like atmospheric corrosion, contamination of soils by some herbicides, insecticides, cleaning products and chemicals can lead to accelerated corrosion at the air/soil interface of galvanized steel posts.

Near the seacoast the rate of corrosion is increased by the presence of soluble chlorides in the atmosphere. Salt aerosols may be generated by breaking surf (coarse aerosols) and by ocean white caps (medium aerosols).



*Typical Corrosivity Categories based on type of coast and distance from the coast.*

Surf coasts and crashing surf generate the most corrosive conditions due to higher salt concentrations from exposure to both coarse and medium salt aerosols, while calm coasts do not generate coarse salt aerosols and are generally relatively benign more than fifty metres from the high tide. Ocean aerosol production is dependent on whitecap coverage, local winds, seabed profile and fetch.

Low lying coastal areas may also host acid sulfate soils, which are naturally occurring soils or sediments that contain iron sulfide. In coastal regions they are formed during and following sea-level inundation when seawater or brackish waters containing dissolved sulfate cover organic-rich environments such as swamps, mangroves, salt marshes or tea-tree.

Under oxygen-depleted conditions, iron present within soils or sediments combines with sulfur from sulfate to form iron sulfides, in particular pyrite ( $\text{FeS}_2$ ). When these sulfides are disturbed and exposed to air, oxidation occurs and sulfuric acid is produced. For every tonne of sulfidic matter that is oxidised, 1.6 tonnes of sulfuric acid is produced (NWPASS, 2000)

Micro-environments play a critical part in determining the life of a galvanized coating in these areas, with building density and location, vegetation and topography playing a significant role in increasing or decreasing the corrosivity, through sheltering effects. Particularly when used as part of a duplex system consisting of paint over galvanizing, the performance of galvanized coatings in these locations relative to other protective systems is outstanding.

In tropical regions and away from surf coasts, the corrosivity, while initially CX to C5 at the high tide line, drops dramatically to C2 within one kilometre and hot dip galvanized steel coatings significantly outperform organic coatings in these locations.

In industrial areas and very close to New Zealand's volcanic region, the presence of atmospheric impurities such as sulphurous gases and airborne chlorides results in the formation of readily soluble zinc salts. These are removed by moisture, which then exposes more zinc to attack. In light industrial areas, galvanized coatings provide adequate protection, but in the extremely corrosive conditions of heavy industrial areas and volcanic regions it is desirable to reinforce galvanized coatings with a paint system resistant to the chemical attack.

**Table 2: Corrosivity in Australia as described in AS 4312**

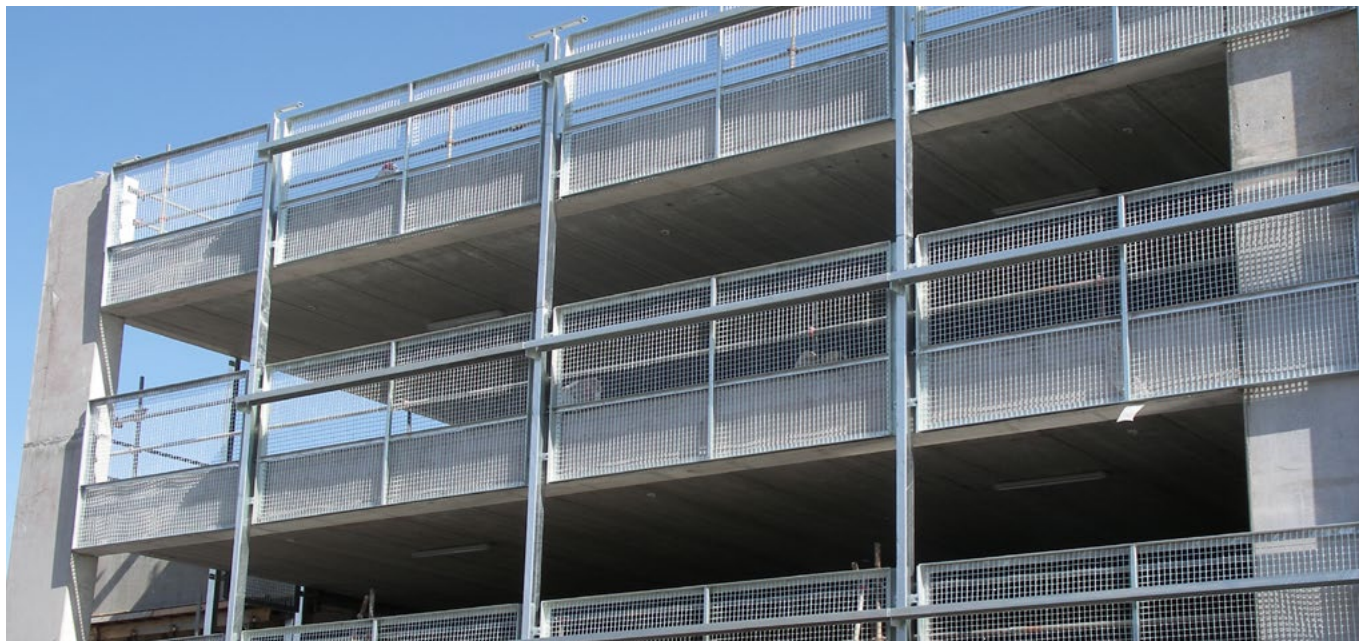
| Category  |                       | Typical examples                                                                                                                                                       | Specific examples                                                                  |
|-----------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <b>CX</b> | Severe surf shoreline | Surf beach shoreline regions with very high salt deposition.                                                                                                           | Some Newcastle beaches. Within 100m of tropical beaches                            |
| <b>C5</b> | Surf Seashore         | Within 200m of rough seas & surf beaches.<br>May be extended inland by prevailing winds & local conditions.                                                            | More than 500m from the coast in some areas of Newcastle                           |
| <b>C4</b> | Calm Seashore         | From 200m to 1km inland in areas with rough seas & surf. May be extended inland by prevailing winds & local conditions.                                                | All coasts                                                                         |
|           |                       | From the shoreline to 50m inland around sheltered bays.<br>In the immediate vicinity of calm salt water such as harbour foreshores.                                    | Some tropical beaches, which move rapidly from C5 to C4 within 500m from the coast |
| <b>C3</b> | Coastal               | From 1km to 10km inland along ocean front areas with breaking surf & significant salt spray.<br>May be extended inland to 50km by prevailing winds & local conditions. | Metro areas of Perth, Wollongong, Sydney, Brisbane, Newcastle, & the Gold Coast    |
|           |                       | From 100m to 3km – 6km inland for a less sheltered bay or gulf.                                                                                                        | Adelaide & environs                                                                |
|           |                       | From 50m to 1km inland around sheltered bays.                                                                                                                          | Port Philip Bay & in urban & industrial areas with low pollution levels            |
| <b>C2</b> | Arid/Urban Inland     | Most areas of Australia at least 50km from the coast.                                                                                                                  | Canberra, Ballarat, Toowoomba & Alice Springs                                      |
|           |                       | Inland 3km – 6km for a less sheltered bay or gulf.                                                                                                                     | Adelaide & environs                                                                |
|           |                       | Can extend to within 1km from quiet, sheltered seas.                                                                                                                   | Suburbs of Brisbane, Melbourne, Hobart                                             |
| <b>C1</b> | Dry indoors           | Inside heated or air-conditioned buildings with clean atmospheres.                                                                                                     | Commercial buildings and internal to most residential houses                       |

**Note:** AS 4312 includes maps showing estimates of corrosivity zones for several major cities of Australia.

**Table 3: Corrosivity in New Zealand as described in SNZ TS 3404**

| Category  |                       | Typical examples                                                                                                                                                                                                                                                                      | Specific examples                                                                      |
|-----------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| <b>CX</b> | Severe surf shoreline | Surf beach shoreline regions with very high salt deposition.<br>Within 500m of some geothermal zones (testing required).                                                                                                                                                              | Some geothermal zones.                                                                 |
| <b>C5</b> | Surf Seashore         | Within 200 m of breaking surf on the west and south coasts of the South Island.<br>Within 100 m of breaking surf on west and south coasts of the North Island.<br>Within 50 m of breaking surf on all other coasts.<br>May be extended inland by prevailing winds & local conditions. | All coasts.                                                                            |
| <b>C4</b> | Calm Seashore         | Within 500m inland of breaking surf.<br>Within 50 m of calm salt water such as harbour foreshores.<br>May be extended inland by prevailing winds & local conditions.                                                                                                                  | All coasts.                                                                            |
| <b>C3</b> | Coastal               | Within 20 km of breaking surf.                                                                                                                                                                                                                                                        | West and south coasts of South Island.                                                 |
|           |                       | Within 5 km of salt water.                                                                                                                                                                                                                                                            | East coast of both islands.<br>West and south coasts of North Island.<br>All harbours. |
| <b>C2</b> | Arid/Urban Inland     | More than 20 km to 50 km from salt water.                                                                                                                                                                                                                                             | West and south coasts of South Island.                                                 |
|           |                       | More than 5 km to 50 km from salt water.                                                                                                                                                                                                                                              | East coast of both islands.<br>West and south coasts of North Island.<br>All harbours. |
| <b>C1</b> | Dry indoors           | Inside heated or air-conditioned buildings with clean atmospheres.                                                                                                                                                                                                                    | Commercial buildings and internal to most residential houses.                          |

**Note:** SNZ TS 3404 includes maps showing estimates of the historical corrosivity rate of steel for major cities and each island. These can be used in conjunction with AS/NZS 2312.2 to estimate HDG durability.



*Christchurch airport carpark is in a C4 Corrosivity Zone. The galvanized frames were installed in 2006 (shown) and were still providing excellent protection when reviewed in 2021.*

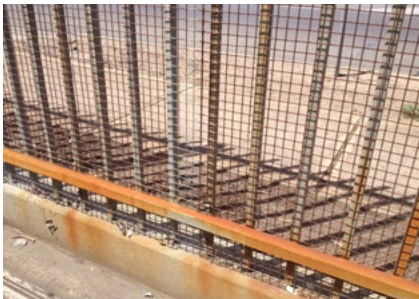
## How service life relates to coating thickness

The service life of any post-fabricated (or batch) hot dip galvanized item is directly proportional to the thickness of the zinc coating. In turn, the galvanized coating thickness is a function of the thickness of the metal and the steel chemistry; typically, the thicker the steel, the thicker the layer of zinc for the same type of steel, as shown in Table 4 (ISO 9223) and Table 6 (ISO 9224).

The exception to this is for hot dip galvanized fasteners, where the Standard, AS/NZS 1214, has a required minimum average galvanized coating thickness of 50  $\mu\text{m}$  for all sizes, again as shown in Table 4 and Table 6. One of the great advantages of hot dip galvanizing is the predictability of the minimum thickness of the zinc for any given steel thickness and type. This is particularly important for sharp edges and complex shapes, where conventional paints don't always cover well.

Continuous galvanizing and electro-galvanizing processes do not follow this relationship, because the processes deliberately restrict the zinc coating thickness and morphology to allow the steel to retain ductility for further manufacturing.

If the conservative first-year corrosion rate estimates from ISO 9223 are used, the corrosion rate data from Table 1 can also be displayed graphically as per Figure 2, allowing for simple estimates of Life to First Maintenance (LTFM) based on measured coating thicknesses.



This galvanized security fence is about 5 years old and in a C3 environment. It has a galvanized wire mesh of an unknown original thickness added for extra security.



The same fence from another angle, showing the galvanizing on the wire mesh has broken down and rust has stained the entire structure, while the tubular after-fabrication galvanized fence is still rust free.



The handrail above was about 7 years old in a C5 wastewater treatment and marine environment when the photo was taken. The post was hot dip galvanized to AS/NZS 4680, while the rail was produced to AS/NZS 4792 HDG300 – or about half the nominal coating thickness of the post. The weld joining the rails was never repaired. Clearly, the after fabrication galvanized post to AS/NZS 4680, with at least double the original coating thickness of the continuously galvanized rail to AS/NZS 4792, has provided superior corrosion protection of the base steel.

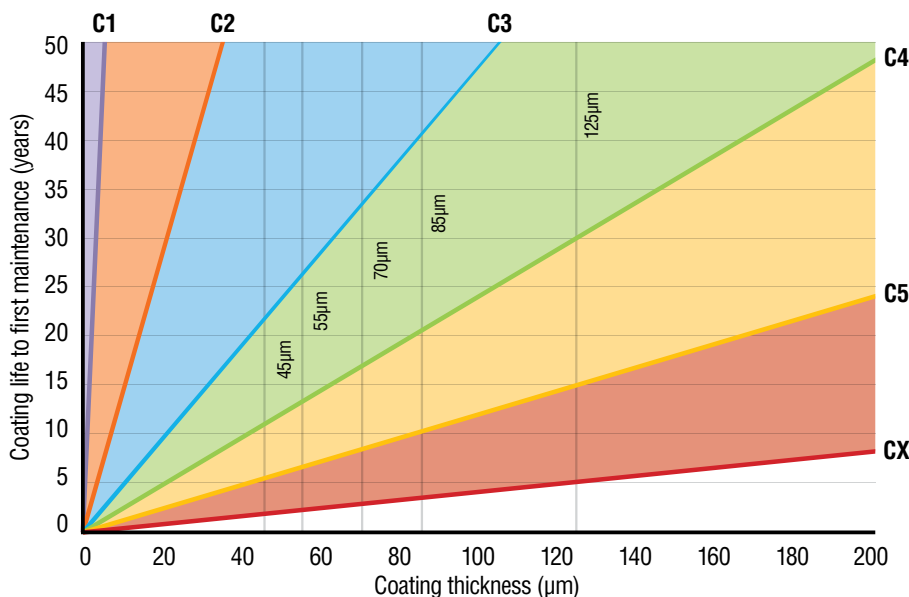


Figure 2: To use the chart, let's say you have a hot dip galvanized structure using steel thicker than 6mm and located in a C4 environment. According to AS/NZS 4680, a piece of steel greater than 6mm thick must have a minimum average of 85  $\mu\text{m}$  zinc. If you follow the 85  $\mu\text{m}$  marker on the chart up to the green C4 line and across to the "coating life to first maintenance" axis, you'll see you have, in the worst case, approximately 20 years until first maintenance (or 5% rust of the substrate steel). In other words, 95% of your coating is still intact, so the structural integrity is not threatened. In the best case, the durability of the coating will be up to 40 years (following the line up to next zone).

## Estimating the durability of hot dip galvanized and zinc coatings using the first-year corrosion rate from ISO 9223

The estimation of the durability of hot dip galvanized coatings using the first-year corrosion rate is straightforward. If the initial corrosion rate and the hot dip galvanized coating thickness is known, the durability is the simple division of thickness by the selected corrosion rate using the straight-line estimation method. Commonly available hot dip galvanized and zinc coated products, and their relative durability using the first-year corrosion rates from ISO 9223 in various environments, are shown in Table 4.

It is important to recognise that the durability of all galvanized and other zinc coatings is generally directly proportional to the coating thickness, which is defined in each manufacturing Standard.

After-fabrication (batch) hot dip galvanizing manufactured to AS/NZS 4680 produces the maximum thickness possible relative to steel thickness, which means it will always provide a longer life to first maintenance than any other hot dip galvanized coating. This contrasts with continuously or specialised coated products, which are produced by different processes.

For continuous coated products, the zinc thickness is accurately controlled, regardless of steel thickness, so that it remains smooth and ductile to allow for later cold forming and for varying manufacturing and end usage and therefore the corrosion protection is necessarily less because of the lower zinc thickness. Performance of these products may vary according to post-coating manufacturing processes, and deformation of heavy gauge sections during roll forming may influence coating performance.



*This cable suspension footbridge at Hallett Cove, South Australia makes extensive use of hot dip galvanized steel in a C5 location.*

**Table 4: Estimated durability for common hot dip galvanized and zinc coatings using first-year corrosion rates from ISO 9223**

| Galvanized/zinc coating system details             |                                                                 |                     |                                          |     | Corrosivity category and estimated life of galvanized/zinc coating (min-max, years) |                 |            |              |           |
|----------------------------------------------------|-----------------------------------------------------------------|---------------------|------------------------------------------|-----|-------------------------------------------------------------------------------------|-----------------|------------|--------------|-----------|
| Australian Standard, product description and class |                                                                 |                     | Galvanized/zinc coating mass & thickness |     | CX<br>Extreme                                                                       | C5<br>Very high | C4<br>High | C3<br>Medium | C2<br>Low |
|                                                    |                                                                 |                     | g/m <sup>2</sup>                         | µm  |                                                                                     |                 |            |              |           |
| AS/NZS 4680                                        | Batch hot dip galvanized fabricated steel                       | HDG900 <sup>1</sup> | 900                                      | 125 | 5 - 15                                                                              | 15 - 30         | 30 - 60    | 60 - >100    | >100      |
|                                                    |                                                                 | HDG600              | 600                                      | 85  | 3 - 10                                                                              | 10 - 20         | 20 - 40    | 40 - >100    | >100      |
|                                                    |                                                                 | HDG500              | 500                                      | 70  | 2 - 8                                                                               | 8 - 16          | 16 - 33    | 33 - >100    | >100      |
|                                                    |                                                                 | HDG390              | 390                                      | 55  | 2 - 6                                                                               | 6 - 13          | 13 - 26    | 26 - 78      | 78 - >100 |
|                                                    |                                                                 | HDG320              | 320                                      | 45  | 1 - 5                                                                               | 5 - 10          | 10 - 21    | 21 - 64      | 64 - >100 |
| AS/NZS 1214                                        | Batch hot dip galvanized structural fasteners <sup>2</sup>      | M8 – M64            | 360                                      | 50  | 2 - 5                                                                               | 5 - 11          | 11 - 23    | 23 - 71      | 71 - >100 |
| AS/NZS 4792                                        | Continuous hot dip galvanized hollow sections <sup>3</sup>      | ZB135/135           | 135                                      | 19  | 0 - 2                                                                               | 2 - 4           | 4 - 9      | 9 - 27       | 27 - >100 |
|                                                    |                                                                 | ZB100/100           | 100                                      | 14  | 0 - 1                                                                               | 1 - 3           | 3 - 6      | 6 - 20       | 20 - >100 |
|                                                    | Specialised hot dip galvanized hollow sections <sup>4</sup>     | HDG300              | 300                                      | 42  | 1 - 5                                                                               | 5 - 10          | 10 - 20    | 20 - 60      | 60 - >100 |
| AS 4750                                            | Continuous electro-galvanized hollow sections <sup>5</sup>      | ZE50/50             | 50                                       | 7   | 0                                                                                   | 0 - 1           | 1 - 3      | 3 - 10       | 10 - 70   |
| AS 1397                                            | Continuous hot dip galvanized roll formed profiles <sup>6</sup> | Z450                | 225                                      | 31  | 1 - 3                                                                               | 3 - 7           | 7 - 14     | 14 - 44      | 44 - >100 |
|                                                    |                                                                 | Z350                | 175                                      | 24  | 0 - 2                                                                               | 2 - 5           | 5 - 11     | 11 - 34      | 34 - >100 |
|                                                    |                                                                 | Z275                | 135                                      | 19  | 0 - 2                                                                               | 2 - 4           | 4 - 9      | 9 - 27       | 27 - >100 |
| AS/NZS ISO 17668                                   | Sherardized or thermal zinc diffusion coated steel <sup>7</sup> | Class 15            | 110                                      | 15  | 0 - 1                                                                               | 1 - 3           | 3 - 7      | 7 - 21       | 21 - >100 |
|                                                    |                                                                 | Class 30            | 215                                      | 30  | 1 - 3                                                                               | 3 - 7           | 7 - 14     | 14 - 42      | 42 - >100 |
|                                                    |                                                                 | Class 45            | 325                                      | 45  | 1 - 5                                                                               | 5 - 10          | 10 - 21    | 21 - 64      | 64 - >100 |

**Notes**

- AS/NZS 4680 specifies a minimum hot dip galvanized coating thickness of 85 µm for normal steel articles > 6 mm thick. However, for certain steel thickness and chemistry combinations, it is sometimes possible to develop a specification capable of third-party verification for hot dip galvanized coatings thicker than 85 µm using the general provisions of that Standard. It is essential to know the composition of the steel to be used, and the galvanizer should be consulted before specifying, as these thicker coatings are not available for all types of steel. Abrasive blasting of the steel surface prior to galvanizing can also be specified to obtain a thicker coating on suitable steels.
- By the nature of the assembly of the fasteners, micro-environments are common around the interface of the screw, bolt, nut, washer and external surface being fixed.
- AS/NZS 4792 ZB100/100 is the usual specification of the coating supplied by Austube Mills for their DuraGal range of tubular products. Thicker coatings (ZB 135/135) are available in a limited range of specific tubular building products.
- AS/NZS 4792 HDG300 is only available in a limited range of CHS and is typically used as sign posts.
- AS 4750 ZE50/50 is the usual specification of the coating supplied by Orrcon for their ALLGAL range of tubular products.
- AS 1397 Z275 is the usual nominal coating mass permitted in the Building Code for items such as brackets and cleats. Z350 and Z450 are the usual coating mass for purlins.
- Thermal diffusion coatings are available in alternative thicknesses although these may require additional surface preparation compared to normal coatings. See AS/NZS ISO 17668 for details.

## Estimating the durability of hot dip galvanized and zinc coatings for steady-state corrosion using ISO 9224

Like all metals, the corrosion rate of zinc exposed to natural outdoor atmospheres is not constant with exposure time and normally decreases with exposure time because of the accumulation of corrosion products on the surface of the exposed zinc.

For exposures of 10 years and up to 30 years, ISO 9224 provides the average and steady-state zinc corrosion range respectively. For long-term exposures beyond 30 years, this Guide uses a more conservative upper limit of corrosion attack after an extended exposure to account for uncertainties in the data by adding two standard deviations to the average value and therefore provides an estimated durability of zinc at the upper 95 % confidence level.

In long-term exposures and when steady-state corrosion can be assumed, such as where the macro-environment dominates the micro-environment or local corrosive influence, this method is more useful to estimate the durability of zinc than shown in Table 4.

NOTE: While sulfur dioxide (SO<sub>2</sub>) exposure levels are generally very low in Australian and New Zealand atmospheric environments, in specific cases where the atmosphere is highly polluted and the deposition rate of SO<sub>2</sub> is more than 80 mg/(m<sup>2</sup>•day) or the concentration is more than 90 µg/m<sup>3</sup>, then Table 4 should be used. An example of where this might occur is in the immediate vicinity of the volcanic regions in New Zealand.

Users of this section are advised to consult with qualified experts when environmental change or localised corrosion such as galvanic corrosion, crevice corrosion or other micro-environmental corrosion could occur over a very-long time.

Changes in rainfall patterns in Australia and New Zealand due to climate change are forecast to be the key driver in effects on the long-term zinc corrosion rate. Modelling by Cole & Paterson provides guidance for Australia. The GAA and GANZ can provide additional guidance for specific exposures.

For some engineering applications, more general guiding corrosion values defined in intervals of average corrosion rates for corrosivity categories may be used. ISO 9224 average corrosion rates of up to 10 years are considered to correspond to the **initial period of exposure**. ISO 9224 average corrosion rates for periods longer than 10 years are considered **steady-state corrosion** rates. Table 5 provides a comparison of the ISO 9223 first year corrosion rates against the ISO 9224, average and steady-state corrosion rates for each corrosivity category.

The uncertainty level for guiding corrosion values defined as averages for initial and steady-state periods is high.

**Table 5 Guiding corrosion values for corrosion rates,  $r_{corr}$ ,  $r_{av}$ ,  $r_{lin}$  of zinc in atmospheres of classified corrosivity categories**

| Values in micrometres per year (µm/year)                                                                       |                           |                           |                           |                           |                     |
|----------------------------------------------------------------------------------------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------|
| Corrosion rate, $r_{corr}$ , during the first year (ISO 9223)                                                  |                           |                           |                           |                           |                     |
| CX                                                                                                             | C5                        | C4                        | C3                        | C2                        | C1                  |
| $8.4 < r_{corr} \leq 25$                                                                                       | $4.2 < r_{corr} \leq 8.4$ | $2.1 < r_{corr} \leq 4.2$ | $0.7 < r_{corr} \leq 2.1$ | $0.1 < r_{corr} \leq 0.7$ | $\leq 0.1$          |
| Average corrosion rate, $r_{av}$ , during the first 10 years (ISO 9224)                                        |                           |                           |                           |                           |                     |
| CX                                                                                                             | C5                        | C4                        | C3                        | C2                        | C1                  |
| $5.5 < r_{av} \leq 16$                                                                                         | $2.7 < r_{av} \leq 5.5$   | $1.4 < r_{av} \leq 2.7$   | $0.5 < r_{av} \leq 1.4$   | $0.07 < r_{av} \leq 0.5$  | $r_{av} \leq 0.07$  |
| Steady-state corrosion rate, $r_{lin}$ , estimated average corrosion rate during the first 30 years (ISO 9224) |                           |                           |                           |                           |                     |
| CX                                                                                                             | C5                        | C4                        | C3                        | C2                        | C1                  |
| $4.4 < r_{lin} \leq 13$                                                                                        | $2.2 < r_{lin} \leq 4.4$  | $1.1 < r_{lin} \leq 2.2$  | $0.4 < r_{lin} \leq 1.1$  | $0.05 < r_{lin} \leq 0.4$ | $r_{lin} \leq 0.05$ |

The total corrosion,  $D$ , is estimated in ISO 9224 as:

$$D = r_{\text{corr}} \times t^b \quad \text{Equation 1}$$

Where:

$t$  is the exposure time (years)

$r_{\text{corr}}$  is the zinc corrosion rate experienced in the first year, described in ISO 9223 ( $\mu\text{m}/\text{year}$ )

$b$  is the zinc-environment-specific time exponent

Equation 1 is observed by ISO 9224 to be valid for exposures of up to 20 years' duration for zinc due to the corrosion product layers increasing in thickness and degree of protection during the exposure period. However, at some point in time beyond 20 years, the layer stabilizes and at this point the corrosion rate becomes linear with time because the rate of zinc loss becomes equal to the rate of loss from the corrosion product layer. There is no significant body of experimental data that show when this might occur and there is no method of predicting this time. However, an approach that yields the maximum estimate of corrosion is to assume that the corrosion rate of zinc becomes linear at 20 years of exposure. In this case, ISO 9224 estimates the corrosion rate using equation 2.

$$dD/dt = b \times r_{\text{corr}} \times (t)^{b-1} \quad \text{Equation 2}$$

Then the total corrosion is estimated in ISO 9224 using equation 3.

$$D(t > 20) = r_{\text{corr}} \times [20^b + b \times (20^{b-1}) \times (t - 20)] \quad \text{Equation 3}$$

**Table 6** provides durability estimates for galvanized and zinc coatings using the above equations with a time exponent value for zinc of 0.873. According to ISO 9224, this provides an upper 95% confidence value (two standard deviations) and is more conservative than the probable values tabled in ISO 9224, which uses the time exponent value of zinc of 0.813. Designers with a higher or lesser appetite for risk can select the time exponents value of zinc that suits the project being considered. Individual estimates can also be performed using the above equations for shorter times. The least risk is associated with the first-year estimates from ISO 9223, however it can lead to design outcomes that are very conservative for some exposures.

Site testing by GAA over the last five years has shown that cut edge protection for continuously galvanized materials is very limited in corrosive locations (including those made from advanced ZM type steels), and the corrosion products developed on the cut edge largely provide only barrier protection, meaning that the coating is susceptible to rapid corrosion at the edge and proceeds away from the cut edge due to galvanic action at a much more rapid rate than might be expected from the surface corrosion rates. This effect increases with increasing steel thickness and is compounded by the effects of coating deformation caused during roll forming, where maximum corrosion rates may occur at the intersection of a roll formed corner and an unprotected cut edge. For fully batch hot dip galvanized steel, this effect does not occur, and rates of corrosion are consistent across the body of an article.

Full details of the approach used and rates of corrosion for other metals, including steel, are available in ISO 9224.



Baanip Boulevard Noise Wall Grovedale.

**Table 6: Estimated durability for common hot dip galvanized and zinc coatings using steady-state corrosion rates from ISO 9224**

| Galvanized/zinc coating system details             |                                                    |           |                                          |     | Corrosivity category and estimated life of galvanized/zinc coating (min-max, years) |                 |            |              |           |
|----------------------------------------------------|----------------------------------------------------|-----------|------------------------------------------|-----|-------------------------------------------------------------------------------------|-----------------|------------|--------------|-----------|
| Australian Standard, product description and class |                                                    |           | Galvanized/zinc coating mass & thickness |     | CX<br>Extreme                                                                       | C5<br>Very high | C4<br>High | C3<br>Medium | C2<br>Low |
|                                                    |                                                    |           | g/m <sup>2</sup>                         | µm  |                                                                                     |                 |            |              |           |
| AS/NZS 4680                                        | Batch hot dip galvanized fabricated steel          | HDG900    | 900                                      | 125 | 6 - 22                                                                              | 22 - 47         | 47 - 97    | 97 - >100    | >100      |
|                                                    |                                                    | HDG600    | 600                                      | 85  | 4 - 14                                                                              | 14 - 31         | 31 - 64    | 64 - >100    | >100      |
|                                                    |                                                    | HDG500    | 500                                      | 70  | 3 - 11                                                                              | 11 - 25         | 25 - 52    | 52 - >100    | >100      |
|                                                    |                                                    | HDG390    | 390                                      | 55  | 2 - 8                                                                               | 8 - 19          | 19 - 40    | 40 - >100    | >100      |
|                                                    |                                                    | HDG320    | 320                                      | 45  | 1 - 6                                                                               | 6 - 15          | 15 - 33    | 33 - >100    | >100      |
| AS/NZS 1214                                        | Batch hot dip galvanized structural fasteners      | M8 – M64  | 360                                      | 50  | 2 - 7                                                                               | 7 - 17          | 17 - 36    | 36 - >100    | >100      |
| AS/NZS 4792                                        | Continuous hot dip galvanized hollow sections      | ZB135/135 | 135                                      | 19  | 0 - 2                                                                               | 2 - 5           | 5 - 12     | 12 - 42      | 42 - >100 |
|                                                    |                                                    | ZB100/100 | 100                                      | 14  | 0 - 1                                                                               | 1 - 3           | 3 - 8      | 8 - 30       | 30 - >100 |
|                                                    | Specialised hot dip galvanized hollow sections     | HDG300    | 300                                      | 42  | 1 - 6                                                                               | 6 - 13          | 13 - 30    | 30 - 97      | 97 - >100 |
| AS 4750                                            | Continuous electro-galvanized hollow sections      | ZE50/50   | 50                                       | 7   | 0                                                                                   | 0 - 1           | 1 - 3      | 3 - 13       | 13 - >100 |
| AS 1397                                            | Continuous hot dip galvanized roll formed profiles | Z450      | 225                                      | 31  | 1 - 4                                                                               | 4 - 9           | 9 - 21     | 21 - 71      | 71 - >100 |
|                                                    |                                                    | Z350      | 175                                      | 24  | 0 - 3                                                                               | 3 - 7           | 7 - 16     | 16 - 54      | 54 - >100 |
|                                                    |                                                    | Z275      | 135                                      | 19  | 0 - 2                                                                               | 2 - 5           | 5 - 12     | 12 - 42      | 42 - >100 |
| AS/NZS ISO 17668                                   | Sherardized or thermal zinc diffusion coated steel | Class 15  | 110                                      | 15  | 0 - 1                                                                               | 1 - 4           | 4 - 9      | 9 - 33       | 33 - >100 |
|                                                    |                                                    | Class 30  | 215                                      | 30  | 1 - 4                                                                               | 4 - 9           | 9 - 21     | 21 - 68      | 68 - >100 |
|                                                    |                                                    | Class 45  | 325                                      | 45  | 1 - 6                                                                               | 6 - 15          | 15 - 33    | 33 - >100    | >100      |

**Notes**

1. This table uses the ISO 9224 method with a time exponent, b, of 0.873 which is the two standard deviations from the time exponent 0.813 used in ISO 9224 (as discussed on page 12).
2. This table would generally be suitable for use when the desired durability of the coating was more than 25 years. Higher risk is associated with higher rates of corrosion such as CX and C5.
3. Where the durability is shown in this table as 10 years or less, it is recommended to use the first-year corrosion rate data shown in Table 4 for evidence of suitability.
4. Refer also to the notes in Table 4.

## Corrosion charts

To assist with comparisons between the first-year corrosion rates derived from ISO 9223 (Table 4) and the long-term corrosion rates derived from ISO 9224 (Table 6), comparison charts are provided to provide examples showing the difference between the Life to First Maintenance (LTFM) of several galvanized coatings in C3, C4 and C5 Corrosivity Categories (Figures 3, 4, and 5, respectively).

NOTE: The LTFM chart for C1 and C2 is not shown as the zinc coating LTFM is estimated to be above 100 years for all structural steel hot dip galvanized to AS/NZS 4680.

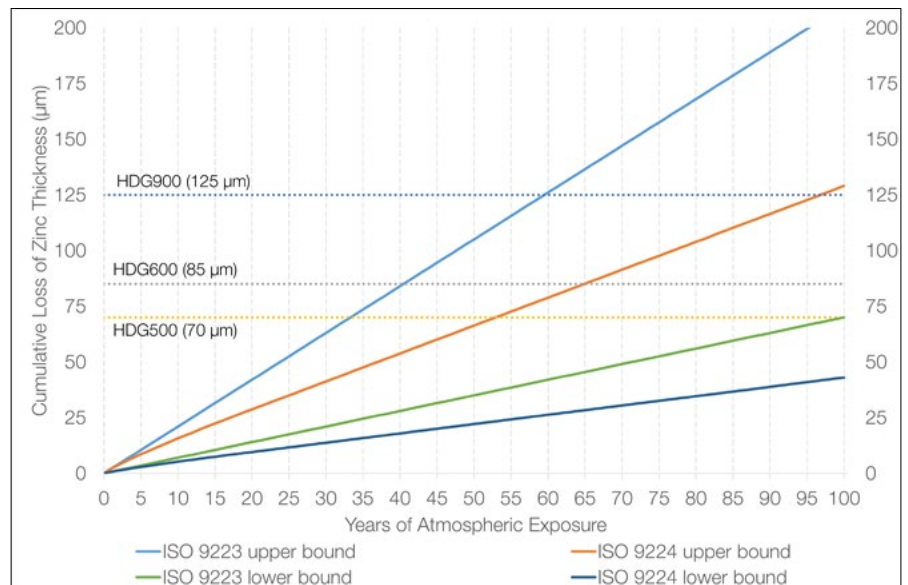
### How to read the charts

As an example, using Figure 2, Corrosivity Category C4, for AS/NZS 4680 HDG500 with a 70  $\mu\text{m}$  coating thickness, the charts are read in the following way:

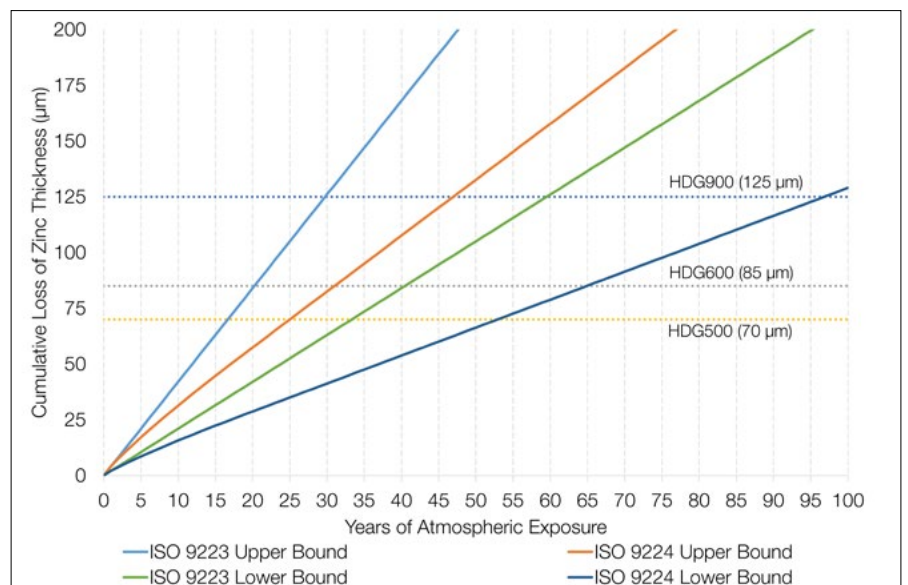
1. To estimate the first-year LTFM from ISO 9223, read along the 70  $\mu\text{m}$  dotted line and find the intersection with the ISO 9223 upper bound (16 years), then read across to find the ISO 9223 lower bound (33 years) as per Table 4.
2. To estimate the steady-state LTFM from ISO 9224, read along the 70  $\mu\text{m}$  dotted line and find intersection with the ISO 9224 upper bound (25 years), then read across to find the ISO 9224 lower bound (53 years) as per Table 6.

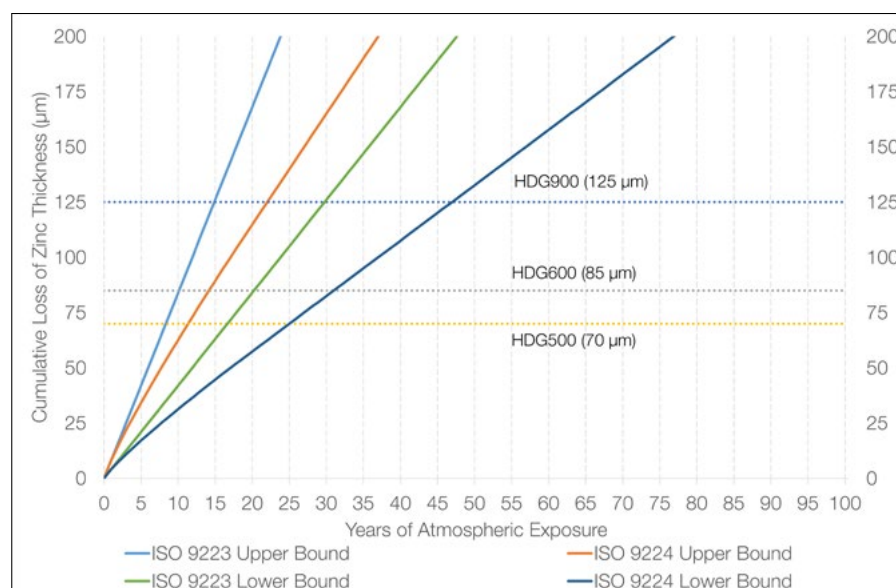
In this manner, the LTFM of any zinc coating thickness up to 200  $\mu\text{m}$  can be estimated. This can be useful if the actual zinc coating thickness varies from the nominal required in the relevant Standard to determine if the expected LTFM meets the end user requirements.

**Figure 3: C3 Corrosivity Category: ISO 9223 and ISO 9224 Zinc Corrosion Loss**



**Figure 4: C4 Corrosivity Category: ISO 9223 and ISO 9224 Zinc Corrosion Loss**



**Figure 5: C5 Corrosivity Category: ISO 9223 and ISO 9224 Zinc Corrosion Loss**

## Galvanized reinforcing steel

Galvanized reinforcing steel is in common usage and is an effective way to ensure the durability of a concrete structure at a much lower capital cost than using stainless steel reinforcing or increasing the concrete cover for uncoated reinforcing steel. Galvanized reinforcing steel does not have the ongoing testing and maintenance costs associated with cathodic protection systems. The galvanizing process has no significant effect on the mechanical properties of reinforcing steel, and all available grades may be successfully galvanized. Galvanized coatings on reinforcing steel provide barrier protection, improved bond strength, a superior passivating layer over normal reinforcement steels and act as a sacrificial anode should the reinforcing steel beneath the coating be exposed. Unlike epoxy coatings, it has excellent abrasion resistance, is unaffected by UV light and has no special requirements for storage, transport, handling and fixing.

Galvanized reinforcing steel is passivated in wet concrete by the formation of an adherent film of calcium hydroxyzincate. In forming this film, the bond strength between the galvanized reinforcing steel and concrete is increased. Galvanized reinforcing steel is stable over a wide pH range (Figure 6) and is completely unaffected by the carbonation of concrete.

Conservatively, galvanized reinforcing steel has a 2 to 2.5 times higher threshold to chloride attack when compared to uncoated reinforcing steel – this more than doubles the time to de-passivation of the reinforcing steel and corrosion initiation. Typically, galvanized reinforcing steel increases the service life of the structure by 4 to 5 times when compared to uncoated reinforcing steel. The time to corrosion initiation of galvanized reinforcing steel in concrete can be modelled using conventional industry chloride ion diffusion models based on Fick's Second Law.

An interactive deterministic model based on Luping and Guilgers solution to Fick's Second Law is available on the GAA website. The model predicts the time to corrosion initiation by calculating the chloride ion concentration profile through the concrete at a specified time, considering variables such as the thickness of cover, surface chloride level (environment), concrete age, chloride diffusion coefficients, type and content of supplementary cementitious materials. Corrosion initiation of the reinforcement is predicted to occur when the chloride ion concentration at the bar surface reaches its critical chloride threshold, and the bar becomes de-passivated. The higher critical chloride threshold of galvanized reinforcement can also be factored into probabilistic models.

The passive behaviour of galvanized reinforcing steel in concrete makes it suitable for use in aggressive environments and is ideally suited for external facades, precast panel joints and surface elements – indeed any application where carbonation or chloride ingress is of concern.

There are no special requirements for the design of concrete using galvanized reinforcing steel and no extra steel or overlay is required. In fact, the higher chloride threshold of galvanized steel allows the option for a thinner cover to be used compared to uncoated reinforcing steel while achieving the same durability.

Should galvanized reinforcing steel become de-passivated, zinc will corrode at a slower rate than iron, and the zinc coating provides a barrier to iron corrosion. And unlike iron oxides, zinc corrosion products will migrate from the galvanized coating and, by reducing the porosity, will slow down the rate of chloride ingress. The relatively smaller volume of zinc corrosion products compared to iron oxides, lessens the expansive pressure generated by the corrosion process, thereby reducing the size of any cracks which may form.

For further information see the Concrete section of the [Design Manual website](#).

## Effect of temperature

Hot dip galvanized coatings will withstand continuous exposure to temperatures of approximately 200 °C and occasional excursions up to 275 °C without any effect on the galvanized coating. Above these temperatures there is a tendency for the outer zinc layer to separate, but the alloy-layer, which usually comprises much of the coating, remains. Adequate protection may often be provided up to the melting point of the alloy layer (around 650 °C).

Bushfires are a special case. In most cases, the temperature of the fire is not sufficiently high enough to damage the steel, or the heat is only applied briefly to the steel. In these cases, the galvanized coating may anneal and the galvanizing diffusion reaction restart, creating a dark zinc-iron alloy layer at the surface.

If this occurs, the steel is undamaged and the galvanized coating will provide ongoing corrosion protection consistent with the remaining galvanized coating thickness.

If access is feasible, it may be possible to clean the galvanized surface of smoke and soot staining with laser cleaning techniques, although this will not restore the original bright silver colour.

A question commonly asked is whether the structure, such as a transmission tower, crash barrier or steel bridge element, has been damaged. The answer is straightforward: if a galvanized coating can be measured; the fire was not sufficiently hot to damage the steel and the structure can remain in place. This is because the galvanized coating will melt or vaporise before the steel is damaged. Determining whether the galvanized coating remains can be done via the same straightforward and non-destructive testing method used in the factory using a magnetic thickness gauge.

## Under water

**General.** The corrosion rate of zinc under immersed conditions can be high in acidic solutions below pH 6 and alkaline solutions above pH 12.5 (Figure 6). Between these limits the rate of corrosion is much lower. The corrosion rate is highly dependent on the amount of dissolved oxygen and carbon dioxide, and the time of exposure, temperature, motion, and fluid agitation all influence the corrosion of zinc in water.

**In mains supply water** of pH 6 to pH 8, calcium and bicarbonate ions are normally present, which leads to precipitation of an adherent calcium carbonate scale on the galvanized coating, together with zinc corrosion products, forming an impervious layer. When sufficiently dense, this layer virtually stops corrosion of the coating, resulting water of normal composition galvanized coatings are most effective and the rate of consumption of the galvanized coating in very long life in many water systems.

Other factors may interfere with this scale deposition. If the water has a high concentration of uncombined carbon dioxide, the protective scale is not formed and full protection never develops. The characteristics of the water supply should be considered in the design of water systems. The presence of even small quantities of dissolved copper in the order of 0.1 parts per million in the water may cause corrosion by rapid pitting.

In unfavourable waters, galvanized steel may require the added protection of galvanic anodes or suitable paint coatings.

It is also important to recognise that the Australian "Plumbing Code" does not permit the use of galvanized pipes for drinking water but does allow them for firefighting systems. Parts of Australia have differing rules in relation to the use of galvanized steels to collect rainwater (e.g., storage tanks) and the subsequent use of that water. Use of galvanized steel is generally acceptable for rainwater collection and storage in New Zealand.

**Pure water.** When newly galvanized articles are immersed in pure water, such as rainwater, there are no dissolved salts present to form the film of insoluble compounds which normally protects the coating from further action. Where practical this condition can be corrected by the addition of controlled amounts of salts to the water during initial immersion. Most natural waters contain sufficient dissolved salts to prevent initial attack, and galvanized tanks and equipment give excellent service. The type and concentration of dissolved species, pH and temperature will all influence the corrosion rate.

**Effect of water temperature.** In cold water of normal composition galvanized coatings are most effective and the rate of consumption of the galvanized coating is very low. This has resulted in almost universal use of galvanized steel for tanks for water storage and transport.

At about 60 °C to 65 °C the rate of corrosion of galvanized coatings increases and continued corrosion resistance depends on early formation of adequate non-flaking scale (Figure 7). Hard water in hot water systems will deposit a scale of calcium and magnesium carbonates on the galvanized surface, nullifying the temperature effect. Soft water may not deposit a protective scale. In such cases, galvanized coatings are unsuitable for hot water systems.

**Sea water.** Galvanized coatings perform relatively well in submerged sea water conditions which are severely corrosive to most protective systems. Dissolved salts present in sea water react with zinc to form a protective layer minimizing corrosive action.

The addition of a suitable paint system or wrap is recommended in areas of severe sea water exposure, particularly in tidal areas and splash zones.

**Table 7: Typical Corrosion Rate for Zinc in Waters**

| Water Type       | Corrosion Rate ( $\mu\text{m}/\text{y}$ ) |
|------------------|-------------------------------------------|
| Sea Water        | 15 – 25                                   |
| Hard Fresh Water | 2.5 – 5                                   |
| Soft Fresh Water | 5 – 10                                    |
| Distilled Water  | 50 – 200                                  |

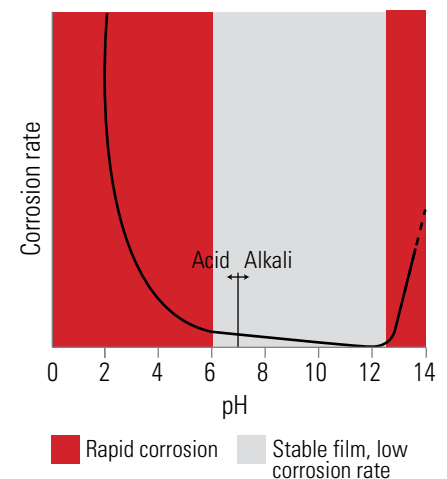


Figure 6: Zinc is stable with a low corrosion rate in the range of pH 6 and pH 12.5.

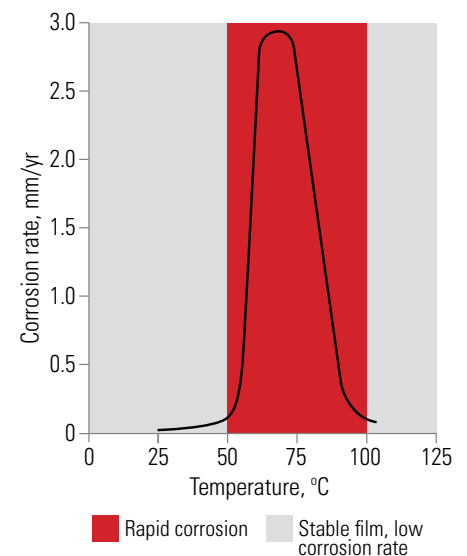


Figure 7: Corrosion of zinc in distilled water as a function of temperature.

## Embedded in soil

Hot dip galvanizing is commonly embedded in soil in a range of applications, with both partial and full embedment having many successful examples. Numerous different soil compositions exist in Australia and New Zealand, with the differences in physical and chemical properties between soils leading to corrosion rates that are rarely uniform between locations.

**Soil Corrosion Rates:** Long-term in-situ investigations in Australia and overseas of over 50,000 buried corrugated metal structures and other steel items allow the durability of hot dip galvanized coatings and steel structures to be estimated with some confidence. Galvanizing usually performs well in soil that is sufficiently free draining to maintain a moisture content below 20%, with typical average HDG loss rates from 2 to 6  $\mu\text{m}/\text{year}$  and steel loss rates once the HDG coating is expended from 10 to 20  $\mu\text{m}/\text{year}$ .

As time passes the corrosion products usually build up on the surface of the galvanizing, leading to a slower corrosion rate after the first couple of years. This effect continues when the last of the zinc has corroded, leaving the underlying steel with a slower corrosion rate than steel that was not initially galvanized. Zinc also corrodes slower than steel in soil and prevents insidious pitting corrosion which commonly occurs on bare steel.

Two Australian and New Zealand Standards are of interest when determining how exposure to soils will affect corrosion rates. AS/NZS 2041.1 provides in-depth information on the soil's corrosivity to buried metal corrugated structures (including galvanized steel) and how engineers can design for durability in the soil's environment. AS 2159 provides requirements for the durability design of piles, using a similar method to AS/NZS 2041.1.

AS/NZS 2041.1 contains both simplified and detailed approaches to designing for durability in soil. If a steel corrosion allowance is included, the design should consider the design requirements from AS 4100 or NZS 3404.1.

**Durability Allowance:** The durability allowance required on bare steel is given explicitly when using the simplified design method from AS/NZS 2041.1 and can also be determined from the estimated life of the zinc coating and steel loss rate using the detailed design method. Structures embedded in soil are commonly designed with an acceptable steel corrosion loss of 1 mm in addition to the structural requirements, although the allowable steel loss should be determined by the engineer for each design based on the local soil corrosivity.

The thickness of the steel can be modified to ensure the member will meet the required service life and the galvanized coating is usually thicker when the thickness of the steel is increased which provides extra durability.

**Simplified Durability Design:** The simplified method is designed to be used for buried corrugated metal structures where the conditions of the installation and soil are known in general, but testing hasn't been carried out on the site (the soil pH can be estimated using simple methods).

If there is any uncertainty as to whether the conditions for using the simplified durability design are met, the detailed durability design procedure should be used. Table 8 lists the requirements for using the simplified method with galvanized steel, as well as whether a durability allowance is required for the base steel and Table 9 is used to determine the metal loss for this method.

**Increasing Durability:** Numerous steps can be taken to help a galvanized steel member embedded in soil reach the desired service life (Figure 8). Some or all the measures in Table 8 may be required depending on the corrosivity of the soil and potential issues identified during the design process. See also Figure 10 for more details on the best design practice for posts embedded in concrete in a corrosive location.

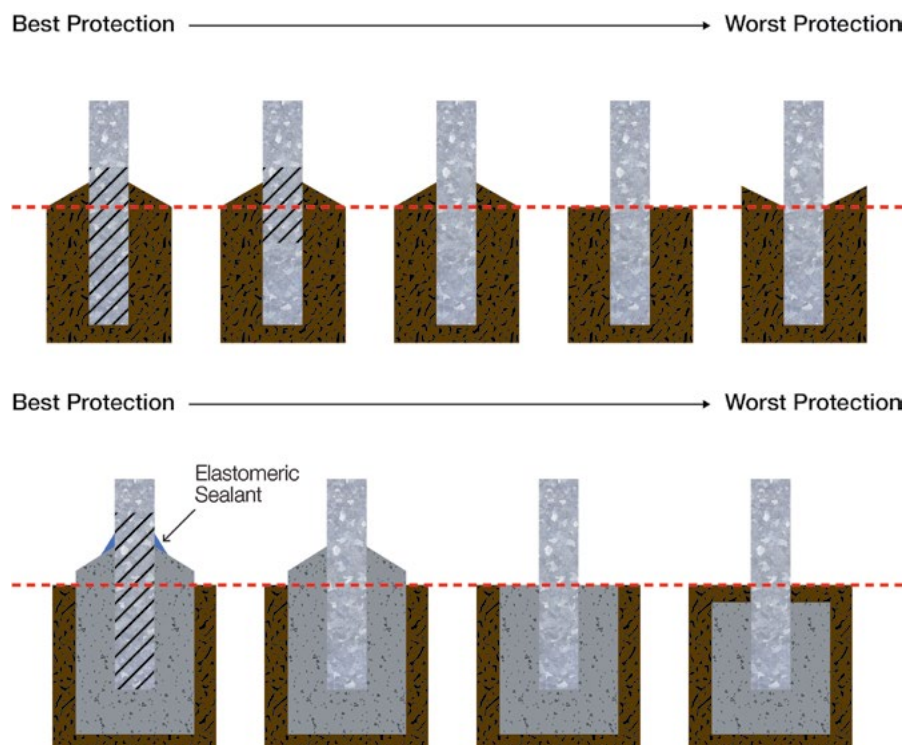


Figure 8: Showing the best design (left) to worst design (right) for galvanized steel embedded in soil and concrete. See also Figure 7 for more details on the best design practice for posts embedded in concrete in a corrosive location.

Table 8: Requirements to use the simplified design method and resulting durability allowance

|                               | No durability allowance                                                                                | 1 mm durability allowance                                 |
|-------------------------------|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| <b>Structure importance</b>   | Lesser importance, < 1.5m in height or width and not expensive to replace                              | Lesser importance, < 3m span and not expensive to replace |
| <b>Design working life</b>    | ≤ 30 years                                                                                             | ≤ 50 years                                                |
| <b>Saline conditions</b>      | Not exposed to airborne salts, salt, or brackish water within 20 km of the coast and not on an estuary |                                                           |
| <b>Corrosive run-off</b>      | No corrosive run-off from mines/industry in the area                                                   |                                                           |
| <b>Fill material draining</b> | Usually dry and free draining                                                                          |                                                           |
| <b>Fill material pH</b>       | In the range of 5 to 8                                                                                 |                                                           |
| <b>Local (native) soil pH</b> | In the range of 5 to 8                                                                                 |                                                           |
| <b>Local (native) soil</b>    | Not saline nor containing sulfates                                                                     |                                                           |

Table 9: Corrosion rates for zinc and steel in soil

| Soil type         | pH     | Resistivity, Ω·cm | Galvanizing loss rate, μm/y                                                 | Steel loss rate, μm/y |
|-------------------|--------|-------------------|-----------------------------------------------------------------------------|-----------------------|
| Non-Corrosive     | 5 – 12 | ≥ 10,000          | 15 for first 2 years and 4 subsequently                                     | 12                    |
| Normal Conditions | 6 – 10 | 2,000 – 10,000    |                                                                             |                       |
| Mildly Corrosive  | 5 – 8  | 1,500 – 2,000     | Seek specialist advice and assume aggressive soil in the detailed procedure |                       |
| Corrosive         | 5 – 10 | > 1500            |                                                                             |                       |

**Preventing Ponding:** When water can pool at the interface between the galvanized steel and soil, a localised corrosion cell can form which results in increased corrosion rates. Ponding can be minimised by building up compacted soil (or concrete) around the interface to promote a natural water run-off and preventing water from running down the member to the interface. If ponding cannot be avoided through a design change, additional barrier protection is recommended at the interface.

**Additional Barrier Protection:** When only part of the member is embedded in soil or the member crosses a soil/groundwater interface, applying an additional coating is recommended to give enhanced corrosion resistance. At an interface between soil and the air there is a risk of accelerated corrosion from the level of compaction and oxygen availability, higher microbial activity in the first 200 mm to 300 mm below the natural soil levels, detritus build-up around the base causing higher levels

of contamination and wetness, and exposure to chemicals such as herbicide, fertiliser, or animal urine.

Accelerated corrosion of the galvanized coating and pitting corrosion of the steel can occur, especially in aggressive atmospheres and wet environments.

For these reasons, where a steel structure is only partially buried, it is recommended designers consider additional protection for the first 250 mm below and above the natural surface.

Many protection methods can be applied over galvanizing to provide additional protection, including epoxy mastic coatings, very high build epoxy coatings, ultra-high build epoxy coatings, powder coating, elastomeric polyurethane or polyurea coatings, bituminous paint (these are often not suitable for UV exposure), corrosion inhibiting fabrics (wrapping tapes), or high-density polyethylene (particularly for piling).

Specialist advice should be sought to ensure the chosen system is suitable for above and below ground use, forms a complete seal against moisture being drawn between the coating and galvanizing by capillary action, and will have excellent long-term adhesion to the galvanized coating.

More information and other design methods are included in the GAA/GANZ Advisory Note AN 42, Hot Dip Galvanizing Embedded in Soil.

## In contact with chemicals

Galvanized coatings are highly resistant to attack over a wide pH range, particularly in moderately alkaline solutions. Unprotected galvanized coatings should not be used with acid solutions below pH 6 or alkaline solutions above pH 12.5.

At intermediate values between these limits a protective film is formed on the zinc surface and the coating corrodes very slowly. Since this range covers most types of water and all but the strongest alkalis, galvanized coatings have wide application for storing and conveying liquids.

Most organic liquids, other than acids, attack zinc only slightly and galvanized coatings are suitable for storage tanks and equipment for handling a wide range of organic chemicals, including motor fuels, creosotes, phenols and esters.

Galvanized coatings are used in refrigeration equipment circulating brine solutions treated with sodium dichromate inhibitor.

**Table 10: Compatibility of galvanized coatings with various media**

| Media                  | Description/Details                                                               | Compatibility                                   |
|------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------|
| Aerosol propellants    |                                                                                   | excellent                                       |
| Acid solutions         | weak, cold quiescent<br>strong                                                    | fair<br>not recommended                         |
| Alcohols               | anhydrous<br>water mixtures<br>beverages                                          | good<br>not recommended<br>not recommended      |
| Alkaline solutions     | up to pH 12.5<br>strong                                                           | fair<br>not recommended                         |
| Concrete               | embedded                                                                          | excellent                                       |
| Detergents             | inhibited                                                                         | good                                            |
| Diesel oil             | sulphur free                                                                      | excellent                                       |
| Fuel oil               | sulphur free                                                                      | excellent                                       |
| Gas*                   | towns, natural, propane,<br>butane                                                | excellent                                       |
| Glycerine              |                                                                                   | excellent                                       |
| Inks                   | printing<br>aqueous writing                                                       | excellent<br>not recommended                    |
| Insecticides           | dry<br>in solution                                                                | excellent<br>not recommended                    |
| Lubricants             | mineral, acid free<br>organic                                                     | excellent<br>not recommended                    |
| Paraffin               |                                                                                   | excellent                                       |
| Perchloroethylene      | dry cleaning fluid                                                                | excellent                                       |
| Sewage                 |                                                                                   | excellent                                       |
| Soaps                  |                                                                                   | good                                            |
| Timber preservatives** | ACQ, CCA, CuAz freshly<br>treated<br>ACQ, CCA, CuAz after curing<br>Boron<br>LOSP | poor<br><br>excellent<br>excellent<br>excellent |

\* Chromate passivation is recommended because moisture may be present.

\*\*See also In contact with timber preservatives.

Transport should be under dry and well-ventilated conditions. When stored on site, material should be sheltered where possible and raised clear of the ground on dunnage or spacers (Figure 8). When shelter is not possible material should be stacked to allow drainage of rainwater. Storage in contact with unseasoned timber, mud or clay will lead to surface staining and in severe cases, premature corrosion.

Clearance for ventilation between stacked galvanized products is necessary under damp or humid conditions to avoid the possibility of wet storage stain and the development of bulky white corrosion product. Attack on the galvanized coating producing white corrosion is caused by the retention of condensation or run-off water between the contacting surfaces under conditions of restricted air circulation.

The attack is frequently superficial despite the relative bulkiness of the corrosion product but may be objectionable because of appearance. In severe cases corrosion product should be removed to allow the natural formation of a protective zinc carbonate film. See GAA/GANZ Advisory Note AN 05, Wet Storage Stain, for more information.

It is common in Australia and New Zealand for the galvanizer to apply a simple passivation treatment as part of the quenching process which will minimise wet storage stain. Under severe conditions passivation should not be relied on and new galvanized products should be packed carefully and protected for shipment and storage.

Hot dip galvanized coatings can withstand chains used during transport, although straps are advised for thicker coatings which are usually more susceptible to damage.

## Sewage treatment

Galvanized coatings perform extremely well by comparison with other protective coatings for steel in the severely corrosive conditions prevailing in most sewage treatment operations. As a result, galvanized steel is used extensively for structures in sewage treatment plants throughout the world.

## Transport and storage

New galvanized products should be handled, transported and stored with the normal care given to any other surface-finished building material. New galvanized steel surfaces that have not yet developed the patina of protective zinc hydroxy carbonate, which normally contributes to the long life of aged coatings, are more reactive and susceptible to premature corrosion under poor conditions of exposure.

## Bimetallic corrosion

**Bimetallic corrosion (also known as galvanic or dissimilar metal corrosion) with resulting rapid consumption of the zinc coating is likely if a galvanized article is installed in contact with brass or copper, particularly in a moist environment. Contact between aluminium and other galvanized surfaces is normally satisfactory.**

Bimetallic corrosion occurs for the same electrochemical reasons as those by which zinc provides cathodic protection for steel but the rate of consumption of zinc coatings by galvanic corrosion may be extremely high.

### Galvanized surfaces in contact with other metals

Bimetallic corrosion requires electrical contact in the presence of an electrolyte and cannot occur in the absence of these factors. Generally hot dip galvanized steel performs well in contact with most common engineering metals when in an atmospheric environment (Table 11), provided the ratio of hot dip galvanized steel to other metals is high. Conversely in immersed conditions, the effect of bimetallic corrosion is significantly increased, and some form of isolation will normally be required.

Practical experience suggests that, where the surface area ratio of zinc to other metal is high and a rating of “a” or “a – b” is indicated, little or no additional corrosion will take place because of the contact. However, where the ratio of surface areas is reduced or the rating is higher, some form of insulation may be required.

The following guidance relates to specific applications concerning zinc coated steelwork in contact with the designated metal or alloy.

**Aluminium** – The severity of increase in bimetallic corrosion due to atmospheric contact with aluminium is relatively low. One application where galvanized steel and aluminium are used in conjunction with one another is aluminium cladding. In this instance, isolation is advised due to the large surface area of the aluminium panels.

Designs utilising **Zincalume** or **Colorbond** should be arranged so that water flows from the galvanized surface onto these materials and not the reverse.

**Copper** – Due to the large potential difference set up by contact between zinc coated steel and copper and copper-containing alloys, electrical isolation is always advised, even in an atmospheric environment. Run-off water from copper surfaces frequently contains small quantities of dissolved copper sufficient to cause attack and rapid deterioration of a zinc coating through dissolution of zinc and chemical deposition of copper.

Where possible, design should avoid run-off of water from copper onto zinc coated articles. Joint faces should be insulated using non-conducting gaskets or mastics and connections should be made with insulating grommet-type fasteners. The design should be arranged so that water flows from the galvanized surface onto the brass or copper surface and not the reverse.

**Lead** – Potential for bimetallic corrosion with lead is low in an atmospheric environment and no problems have been reported concerning, for example, the use of lead flashing with zinc or zinc coated products and the use of lead in fixing galvanized posts.

**Stainless steel** – The most common use of stainless steel with zinc coated steel is in the form of nuts and bolts in an atmospheric environment. Given the low potential for bimetallic corrosion and the small surface area of stainless-steel fasteners, bimetallic corrosion would not normally be an issue although, as always, best practice remains isolation using insulating washers.

**Table 11: Performance of galvanized steel in contact with other metals**

| Metal           | Atmospheric Exposures |                  |        | Immersed   |          |
|-----------------|-----------------------|------------------|--------|------------|----------|
|                 | Rural                 | Industrial/Urban | Marine | Freshwater | Seawater |
| Aluminium       | a                     | a – b            | a – b  | b          | b – c    |
| Brass           | b                     | b                | a – c  | b – c      | c – d    |
| Bronze          | b                     | b                | b – c  | b – c      | c – d    |
| Cast iron       | b                     | b                | b – c  | b – c      | c – d    |
| Copper          | b                     | b – c            | b – c  | b – c      | c – d    |
| Lead            | a                     | a – b            | a – b  | a – c      | a – c    |
| Stainless steel | a – b                 | a – b            | a – b  | b          | b – c    |

#### Key

- a.** The zinc coating will suffer either no additional corrosion or, at worst, only slight additional corrosion which is usually tolerable in service.
- b.** The zinc coating will suffer slight or moderate additional corrosion which may be tolerable in some circumstances.
- c.** The zinc coating may suffer severe additional corrosion and protective measures will usually be necessary.
- d.** The zinc coating may suffer severe additional corrosion and contact should be avoided.

## Galvanized coatings for buildings and structural steel

**A vital factor to be considered in the assessment of coating systems for buildings and structural steel is the relative effectiveness of coatings.**

No protective coating applied to a structure after completion can provide the same protection as a galvanized coating which covers the entire surface of all components, automatically protecting areas to which later access may be difficult or impossible.

When steel members, fascia's and other components which are to receive a final decorative or protective coating are galvanized, no surface deterioration will occur during storage, handling, erection or waiting time until completion of the project. Galvanized coatings can save considerable time and cost which might otherwise be necessary for rectification of damaged or corroded surfaces.

**Exposed frame structures.** Open frame industrial steel structures which are not protected by roofing or cladding are particularly vulnerable to corrosion. Normally they are sited in industrial areas and, frequently, maintenance access is difficult. In these circumstances no other coating system matches the economy and performance of galvanized coatings. Even in the most severe atmospheres a duplex system of galvanizing-plus-paint will usually provide the best practical balance between cost and the longest possible maintenance-free operating period. The galvanized coating provides a stable base for the paint film, ensuring far longer coating life, and protection should the paint film be damaged through impacts or abrasion in service.

**Internal steelwork in industrial buildings.** Galvanized coatings are ideal for many structures which house industrial processes; in structures where the humidity of contained air is high, as in breweries, paper manufacture and sewage treatment; and in food processing and other areas where cleanliness is essential. Whether used alone or in combination with paint coatings, galvanized steel will provide very low total long-term cost, with longer maintenance-free service periods.

### In contact with building materials

Galvanized coatings give invaluable protection to steel used in all sections of the building industry. The slight etching action upon galvanizing by mortar, concrete, and plaster ceases after curing.

Galvanized reinforcement is widely specified to increase the durability of concrete elements. Durability can be increased compared to uncoated rebar by 2-6 times without increasing cover. See Galvanized reinforcing steel in this Guide.

### Posts embedded in concrete

Hot dip galvanized posts are often embedded in concrete footings to extend the life in aggressive soils or for design reasons such as to provide a higher tolerance to a member's overturning moment. The concrete/soil/ steel/air interfaces should be designed and built correctly, including extending the concrete at least 250 mm below the soil level, ensuring the concrete extends above the natural soil level and slopes away from the steel at a 10° angle (at least) to prevent ponding, and adding additional barrier protection such as suitably thick durable paints or wraps when the exposed atmospheric corrosivity category is C3 or above (Figure 10). Concrete, bricks and mortar are susceptible to corrosion in acid sulfate soils and will not provide significant protection in these circumstances. The best solution is to modify the fill, alter the concrete design and/or increase the cover if concrete use is required.

### In contact with timber

Galvanized steel is often used in conjunction with timber in structural steel and as components (bolts, nails, plates, etc). When galvanized steel products and fasteners are installed in direct contact with unseasoned timber it will be necessary to protect them by the application of suitable paint, wrap or other isolating barrier (e.g., nylon washers or sleeves).

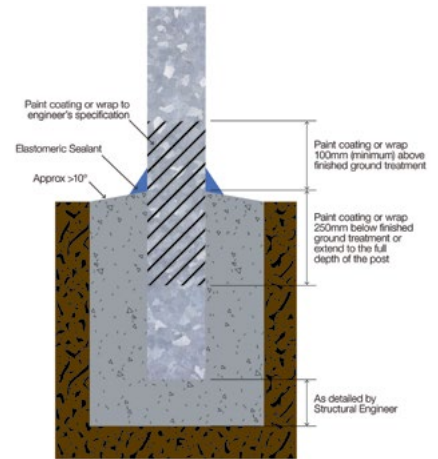


Figure 10: Best practice options for embedding hot dip galvanized posts in concrete.

In structural applications in atmospheric or embedded conditions, galvanized steel may be required to be isolated from timber through suitable paints, wraps or other isolating barriers to increase the durability. A common application here is as I-beam or channel retaining wall posts with timber sleepers, where the timber facing elements are painted with an isolating paint.

According to the EWPAA, timber products treated with cured copper-based preservatives (ACQ, CCA, CuAz) are suitable for use with galvanized steel where the building is protected by a eave overhang of minimum 600 mm, average rainfall does not exceed 1000 mm (e.g. Melbourne, Adelaide & Perth but not Sydney or Brisbane) and the building or structure is designed and built to exclude 'moisture traps' both during erection and in subsequent use (Source: EWPAA Technical Note Issue 2, 2012).

Boron treated timber is suitable for indoor applications only and galvanized steel of all types is well suited for use in this application.

LOSP treated products are excellent for use with galvanized steel, although exposure of products to coastal areas will reduce durability of the structure and is not recommended.

## Lintels

A lintel is a load bearing beam, often made of steel, which spans the top of a door, window, or other opening (for example, a garage) in a building. The lintel acts to distribute the load to the edges of the opening and is designed to minimise the deflection across the opening. Access for maintenance is not always easy because lintels are built into the structure, so it is normally necessary to specify a solution that will last at least the design life of the building. In most situations a 50-year design life is specified.

Once rusting begins in a lintel, it cannot be stopped without major costs and disruption to the building fabric. The exposed surface may be repainted but there is no treatment for concealed areas. The advance of corrosion will continue until the expansion of steel corrosion products causes cracking of brickwork and ultimately, serious structural damage.

The durability of lintels is dealt within the Australian Standard, AS 2699.3 and this Standard includes a requirement that lintels must last at least 50 years without adversely affecting the function of the surrounding masonry. The structural design and installation of lintels and their supports is covered in other Standards, including AS 3700, AS 4773.1, AS 4773.2, and AS 4100.

**Table 12: Hot dip galvanized lintels available in AS 2699.3**

| Durability class of lintel | Material or protective requirements                                                                                |
|----------------------------|--------------------------------------------------------------------------------------------------------------------|
| R1<br>R2                   | Hot dip galvanized to AS/NZS 4680 with a minimum average coating thickness of 42µm                                 |
| R3                         | Hot dip galvanized to AS/NZS 4680 with a minimum average coating thickness of 85µm                                 |
| R4                         | Hot dip galvanized to AS/NZS 4680 with a minimum average coating thickness of 85 µm plus a 4D or 4I paint top-coat |

**Note:** Details of the 4D and 4I paint systems are shown in the GAA Painting Guide.

**Table 13: Comparison of Durability Class (masonry) and Corrosivity Category (atmospheric exposure) based on distance from the coast**

| AS 2699.3        |                  |                 | AS 4312              |                  |                 |
|------------------|------------------|-----------------|----------------------|------------------|-----------------|
| Durability class | Typical distance |                 | Corrosivity category | Typical distance |                 |
|                  | Surf coast       | Sheltered coast |                      | Surf coast       | Sheltered coast |
| R1 & R2          | >10km            | >1km            | C2                   | >50km            | >10km           |
|                  |                  |                 |                      | 10km to 50km     | 1km to 10km     |
| R3               |                  |                 |                      |                  |                 |
|                  | 1km to 10km      | 100m to 1km     | C3                   | 1km to 10km      | 50m to 1km      |
| R4               | <1km             | <100m           | C4                   | 200m to 1km      | <50m            |
|                  |                  |                 | C5                   | < 200m           | N/A             |



*The interface of hot dip galvanized steel and concrete can be protected with a non-conductive paint to slow corrosion.*

The ABCB Housing Provisions Standard 2022, section 5.6.7 says steel lintels must comply with the corrosion protection requirements of Table 5.6.7b in accordance with AS 2699.3. The Standard has also been simplified so there is now a single table of acceptable design solutions, indexed by durability classification (Table 12). An acceptable design solution for a durability class is also considered suitable for lower durability classifications. For example, an R3 solution can be used for an R2 design.

Any lintel with a coating that is modified, i.e., by cutting, welding, or where damaged, must have the coating restored to provide an equivalent level of protection provided by the original coating.

Each design solution description has been carefully written to ensure that when purchasers specify from the table, they can easily check compliance – and in most cases these tests can be carried out quickly and on a building site if required.

Tests and labelling requirements for coating thickness are included in the Standard in a new Appendix and the purchaser can ask that a conformance report is supplied with their purchase. Lintel manufacturers must have available conformance reports on their generic product range. Further compliance requirements are found in the need to permanently mark each lintel with the Standard, the durability class, and the manufacturer's name.

#### Determining the required durability class:

A new informative Appendix is included in the Standard which shows the simplified relationship between the required durability classification of masonry described in AS 3700 and corrosion in normal atmospheric conditions which is defined in AS 4312 (Table 13). Specifiers can use this simplified relationship to determine the likely durability classification based on the location of a specific building, or to assist in developing a performance solution using the requirements in the NCC.

AS 4312 C2 or C3 corrosivity category can be 10 km to 50 km from a surf coast or 1 km to 10 km from a sheltered coast and this fits into R2 or R3 durability classification. In most cases, an acceptable design solution from R3 would normally be chosen.

Durability class R4 covers both C4 and C5 corrosivity categories for marine exposure. It is important to recognise that the corrosion rate of hot dip galvanized steels increases by up to four times for the highest rate of C5 compared to the lowest rate of C4. For this reason, lintels directly exposed to a surf coast (C5) would normally require a 316 stainless-steel solution.

The new version of AS 2699.3 includes 304 stainless-steel in the R3 category. Users need to be aware that, although suitable for use in these applications, 304 stainless-steel is susceptible to 'tea staining' in marine environments and some homeowners may not be happy with a stained surface, so extra surface preparation or a paint topcoat could be required.

**Performance Solutions:** Just like the previous edition of AS 2699.3, designers can specify alternative materials or coatings to those shown in the Standard. In this edition there are no instructions on how to demonstrate conformance, except that the alternative design solution must include suitable evidence to support the use of the alternative material. This evidence provided must be in writing from a laboratory, include the methods used to determine the durability and results of the tests carried out.

The new edition of the Standard specifically excludes accelerated salt spray tests, such as ASTM B117, for coatings containing zinc unless appropriate corroborating long-term atmospheric exposure tests have been conducted, as these salt spray tests are known to trigger the wrong failure mechanism, leading to artificially lower durability times for zinc coatings.

## Duplex systems – Paint over galvanizing

In service conditions where the life of the hot dip galvanized steel may be limited, the addition of a paint finish, (a duplex coating system) can extend the service life of the steel. If the paint system is maintained by appropriate reinstatement from time to time, so as to preserve the galvanized surface and the paint, the service life of the structure should be unlimited.

There are three main reasons for painting hot dip galvanized steel. These are:

**Decorative** – to create an aesthetic colour and gloss or provide an identifying or camouflaging colour

**Enhanced durability** – to increase the service life in corrosive locations

**Increased chemical resistance** – in a situation where hot dip galvanizing alone may be vulnerable, such as outside the pH range of 6 to 12

In corrosive locations, such as severe coastal or industrial service, an appropriately maintained duplex system will provide a synergistic improvement over and above the separate contributions of each coating. Research has shown the increase in service life can be 1.5 – 2.3 times over the sum of individual coatings service life.

The type of paint selected, and the surface preparation will vary depending upon the environment and the aesthetic demands. Detailed advice is contained in the [Guide to paint systems for hot dip galvanized steel in atmospheric service \(duplex coatings\)](#).

It is essential for service life that the steel is fabricated to be suitable for painting before it is hot dip galvanized, other than abrasive blasting unless required for the hot dip galvanized coating. Clause 9.10 of AS/NZS 5131 provides instruction on surface preparation for hot dip galvanized articles that are to be subsequently overcoated. In this case the fabricator must prepare the surface of the fabricated steel before galvanizing as follows:

- secondary steelwork to P2 (thorough treatment)
- primary steelwork to P3 (very thorough treatment)

Any welds that are ground smooth and on a planar surface will be visible after galvanizing as the parent metal of the weld will differ in reactivity to the main structural items. Planar weld joints should therefore be avoided when a critical function of the duplex coating is decorative.

## Bibliography

1. **Porter, F C.** Zinc Handbook, Properties, Processing and Use in Design. s.l.: Marcel Dekker Inc, 1991.
2. **Standards Australia.** *Atmospheric corrosivity zones in Australia.* Sydney: SAI Global, 2008. AS 4312.
3. **Department of Sustainability, Environment, Water, Population and Communities.** *State of the Air in Australia 1999 - 2008.* Canberra: Australian Government, 2011.
4. *Industrial pollution and its impact on corrosion and corrosion mitigation practices.* **Bartlett, Don J.** 2001. Australasian Corrosion Association Conference. Vol. Paper No. 44.
5. **King, G A and Carberry, B.** *Atmospheric corrosivity in the greater Newcastle region.* s.l.: CSIRO DBCE, 1992. Technical Report 92/3.
6. Corrosivity mapping used for transmission line maintenance by the Electricity Trust of South Australia. **King, G A, Kapetas, J and Bates-Brownsword, D.** Adelaide: s.n., 1994. Australasian Corrosion Association Conference 34. Vol. Paper No. 60.
7. **King, G A, Martin, K G and Moresby, J F.** A detailed corrosivity survey of Melbourne. Melbourne: CSIRO DBR, 1982.
8. **Goklany, Indur M.** Cleaning the air: the real story of the war on air pollution. Washington DC: Cato Institute, 1999.
9. **Knotkva D and Porter F** 1994 Longer life of galvanized steel due to reduced sulphur dioxide pollution in Europe, Ed. proc Intergalva 94, p GD 8/1-8/20 pub. EGGA London.
10. **Standards New Zealand.** *Durability requirements for steel structures and components.* Wellington: Standards New Zealand, 2018. SNZ TS 3404.
11. **Standards Australia/Standards New Zealand.** Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings - Part 2: Hot dip galvanizing. Sydney/Wellington: SAI Global, 2014. AS/NZS 2312.2.
12. **International Organization of Standardization.** Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination and estimation. Geneva: International Organization of Standardization, 2012. ISO 9223.
13. **International Organization for Standardization.** Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures - Part 1: General principles of design and corrosion resistance. Geneva: International Organization for Standardization, 2017. ISO 14713-1.
14. **Standards Australia/Standards New Zealand.** *Hot-dip galvanized (zinc) coatings on fabricated ferrous articles.* Sydney and Wellington: SAI Global, 2006. AS/NZS 4680.
15. **Standards Australia.** Hot-dip galvanized coatings on threaded fasteners (ISO metric coarse thread series) (ISO 10684:2004, MOD). Sydney / Wellington: SAI Global, 2016. AS/NZS 1214.
16. **International Organization for Standardization.** Corrosion of metals and alloys — Corrosivity of atmospheres — Guiding values for the corrosivity categories. Geneva: International Organization for Standardization, 2012. ISO 9224.
17. **Standards Australia.** Continuous hot-dip metallic coated steel sheet and strip — Coatings of zinc and zinc alloyed with aluminium and magnesium. Sydney: SAI Global, 2011. AS 1397.
18. **Standards Australia / Standards New Zealand.** Hot-dip galvanized (zinc) coatings on ferrous hollow sections, applied by a continuous or a specialized process. Sydney / Wellington: SAI Global, 2006. AS/ NZS 4792.
19. **Standards Australia.** Electrogalvanized (zinc) coatings on ferrous hollow and open sections. Sydney: SAI Global, 2003. AS 4750.
20. **ASM International.** Metals Handbook. Volume 13 "Corrosion". s.l.: ASM International, 1987.
21. **Slunder, C J and Boyd, W K.** *Zinc: its corrosion resistance.* s.l.: International Lead Zinc Research Organization, 1983.
22. **Robinson, John.** *Predicting the in-ground performance of galvanised steel.* s.l.: BlueScope Steel, 2005.
23. **Standards Australia / Standards New Zealand.** *Buried corrugated metal structures - Part 1: Design methods.* Sydney / Wellington: SAI Global, 2011. AS/NZS 2041.1.
24. **Galvanizers Association of Australia.** *Durability of hot dip galvanized steel in soil.* Melbourne: Galvanizers Association of Australia, 2018. AN 42.1.
25. **Standards Australia.** *Piling - Design and installation.* Sydney: SAI Global, 2009. AS 2159. **Galvanizers Association of Australia.** *Guide to paint systems for hot dip galvanized steel in atmospheric service (duplex coatings).* 2.2. Melbourne: Galvanizers Association of Australia, 2018.
26. **Cole IS, Muster TH, Paterson DA, Furman SA, Trinidad GS and Wright N,** *Multi-scale modeling of the corrosion of metals under atmospheric corrosion,* Electrochimica Acta 56 (2011) 1856-1865.
27. **I. S. Cole & D. A. Paterson** (2010) *Possible effects of climate change on atmospheric corrosion in Australia,* Corrosion Engineering, Science and Technology, 45:1, 19-26, DOI: 10.1179/147842209X12579401586483

This is one of a series of Technical Guides on the durability, sustainability, application, design, process, bolting, welding and painting of galvanized steel. We also offer a range of free Advisory Notes on various aspects of hot dip galvanizing, along with a Durability Estimator App.

To download the Technical Guides, Advisory Notes and access the Durability Estimator App, go to <https://gaa.com.au/technical-publications/>

This content, and more, is also available as web content at our dedicated Design Manual website <https://designmanual.gaa.com.au/>

We provide trusted information on all aspects of galvanizing. A hub for engineers, architects, specifiers, fabricators, and consultants looking for information on the superior protection and unmatched advantages of adding a galvanized coating to steel.

By protecting steel from corrosion, hot dip galvanizing performs an invaluable environmental service. Hot dip galvanizing significantly prolongs the life of steel, contributing to the preservation of our natural resources.



Tier 1 reservoir project in Queensland. Photo courtesy of NEACH

## We're here to help

Are you looking for more information or advice on the durability, sustainability, application, design, process, bolting, welding or painting of galvanized steel? Want advice on a specific situation or issue? You're in the right place! We would love to hear from you.



 [Galvanizers Design Manual](https://designmanual.gaa.com.au/)



 Level 6  
124 Exhibition Street  
Melbourne VIC 3000  
Australia

 [GAA website](https://gaa.com.au/)  
Find a galvanizer, bath size and technical support

@ [gaa@gaa.com.au](mailto:gaa@gaa.com.au)

 +61 3 9654 1266



 [GANZ website](https://galvanizing.org.nz/)  
Find a galvanizer, bath size and technical support

@ [enquiry@galvanizing.org.nz](mailto:enquiry@galvanizing.org.nz)

This document is intended to inform readers of issues and developments in the field of hot dip galvanizing. Any advice given, information provided, or procedures recommended may be based on assumptions which while reasonable, may not be applicable to all environments and potential fields of application and its accuracy, reliability or completeness is not guaranteed and should not be used as a substitute for professional advice. GAA, GANZ, and their employees disclaim all liability and responsibility for any direct or indirect loss or damage which may be suffered by the recipient through relying on anything contained or omitted in this publication.

© Galvanizers Association of Australia/Galvanizing Association of New Zealand, 2025

