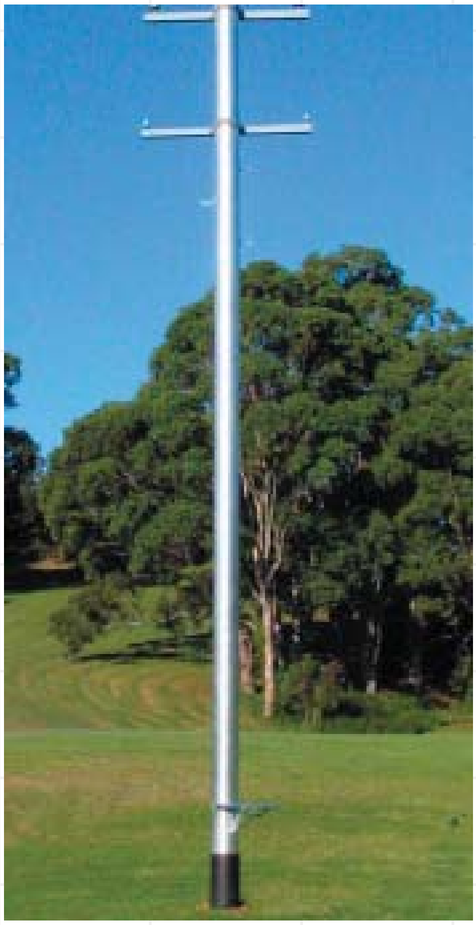
05. GALVANIZED STEEL IN-GROUND

INTRODUCTION

The use of steel underground is not new. There are many applications where steel is used in the ground, from simple applications like sign posts and fence posts, to engineered applications like piling and foundations. Over the past five years, new applications have been developed for steel foundation products. These products offer significant performance and cost advantages over traditional masonry and timber alternatives.

Alternative methods of installing steel utility poles for lighting and power distribution have been developed using direct embedded poles to reduce the installation costs and environmental impact of installation.

It is not practical to install expensive corrosion management technologies on many of these embedded steel products, as is the case for more critical infrastructure such as pipelines and tunnels. An understanding of the mechanism of corrosion will allow a predictable life to be designed into utility steel products that are to be used in-ground for new piers, piling and pole applications. This article has consolidated information from a number of authoritative sources to assist in evaluating the life of steel in-ground products.



Galvanized steel poles have been direct buried for many years. BlueScope Steel's newly developed Sureline pole is designed for a minimum of 50 years in-ground service, using heavy galvanized coatings and membrane systems at the ground line.

STEEL CORROSION IN-GROUND

In the atmosphere, most materials have predictable modes of corrosion that are largely dependent on pollution levels, temperature and relative humidity. Once the important parameters are identified, the mechanism of metallic corrosion will then be common to all the products that are within that climatic zone.

In-ground situations are vastly different because of the wide local variations in soil chemistry, moisture content and conductivity that will affect the way coated or uncoated steel will perform in the ground.

Research into steel corrosion in soil started in the early years of this century, when Melvin Romanoff began a study for the National Bureau of Standards that continued for over 40 years. Many other corrosion-in- soil research projects were undertaken concurrently or subsequently.
Much of this activity has taken place in Australia sponsored by various road authorities and private enterprise companies such as BlueScope Steel and Ingal Civil Products, in evaluating in-ground corrosion performance on a range of products from culverts to piling.

Corrosion of metals in soil is extremely variable and while the soil environment is a complex one, it is possible to draw some conclusions about soil types and corrosion.

Any given soil will appear as a very heterogeneous electrolyte which consists of three phases:

- The solid phase made up of the soil particles which will vary in size and will vary in chemical composition and level of entrained organic matter.
- The aqueous phase which is the soil moisture - the vehicle which will allow corrosion to take place.
- The gaseous phase which consists of air contained in the soil's pores. Some of this air may dissolve in the aqueous phase.

THE SOLID PHASE

Soils are commonly classified according to the general size range of their particulate component. Sandy, silty and clay soils are thus identified from the predominant size range of their inorganic particles. Convention classifies particles over 0.07mm to around 2mm as sands, particles from 0.005mm to 0.07mm as silts and 0.005mm smaller as clays. Soils rarely exist with only one of these components present.

The various groups of sand, silt and clay make up the soil classifications on the basis of their particle size.

Clay soils are characterised by their ability to absorb water readily, the level of which is determined by the nature of the clay. For this reason, clay soils present a significantly higher corrosion risk than sandy soils. For this reason also, the nature of the soil on the surface may not reflect its nature below the ground.

THE AQUEOUS PHASE

Corrosion will only occur in the presence of moisture that contains ions that will transmit the electric current maintaining corrosion activity. There are several types of soil moisture. These are:

- free ground water
- gravitational water
- capillary water.

The free ground water is determined by the water table, which may range from near ground level to many metres below the surface. This is the least important factor in determining corrosion of buried steel as most installations are above normal water tables. Where high water tables bring ground water in contact with embedded steel, corrosion will progress as if the steel were in an immersed environment.

Gravitational water arises from rainfall or man-made irrigation and will soak into the soil at a rate determined by its permeability. This will increase the period of wetness of the steel's surface and this in turn will impact on the soil's corrosive effects, depending on the conductivity of the gravitational water. Where regular rainfall occurs, most soluble salts may be leached from the soil over time, which will reduce the corrosive effects of gravitational water. Gravitational water will ultimately end up in the water table.

INGAL Civil Products has been installing buried galvanized structures for over 60 years. Performance monitoring of installed structures has indicated significantly better performance than originally expected.

Capillary water is water that is entrained in the pores and on the surfaces of the soil particles. The ability of soil to retain moisture is obviously important to plant growth. It is the capillary water that is the prime source of moisture in determining corrosion rates of steel in soil.

The fluctuations in water content in soil due to precipitation and evaporation cause a variation in oxygen content, as drier soils allow more oxygen access and oxygen concentration cell formation may be enhanced.

SOIL CHEMISTRY

Acid or alkaline conditions develop in the soils depending in their parent rock and the geological or man-made activity that may impact on them over time. Most soils are in the pH range of pH 5.0 to pH 8.0. Highly acidic soils are relatively rare, and generally occur in swamp soils or areas subjected to high accumulations of acidic plant material such as pine needles.

Soluble salts are essential to plant growth and are a major factor in corrosion. These salts may include salts of potassium, sodium, calcium and magnesium. Salts such as calcium and magnesium, while initially promoting corrosion, frequently act beneficially as their insoluble oxides and carbonates become corrosion inhibitors over time.

Bacteria in soil is another factor that is important in corrosion activity. Sulfates can promote rapid bacteriological corrosion of steel because of sulphate reducing bacteria. Hydrocarbon-using bacteria can accelerate failure of organic coatings used underground also.

Soil has to be able to conduct electricity to participate in the corrosion of buried steel. The resistivity of the soil is used as an important measure of soil corrosivity. The higher the resistivity, the more the resistance to current flow moving between anodic and cathodic regions of the steel.

Regions of moderate or high rainfall will commonly have low levels of soluble salts in the soil, while desert soils may have very high salt levels. Some of the most aggressive soils in Australia are located in desert areas like the Simpson Desert clay pans have higher corrosion rates for galvanized coatings than many surf-side environments.

ESTIMATING SOIL CORROSIVITY

A great deal of case history data and specific research has been accumulated and this is invaluable in evaluating the potential for corrosion for various types of buried structures. While there is no easy answers, the German Gas and Water Works Engineers Association has developed a standard soil corrosivity assessment technique which rates the various factors that influence corrosion of steel in the ground detrimentally or beneficially. The sum of these factors gives an approximate corrosion rating.

TABLE 1
SOIL CORROSIVITY ASSESSMENT TECHNIQUE

Item	Measured value	Mark
Soil composition	Calcareous, marly limestone, sandy marl, not stratified sand.	+2
	Loam, sandy loam (loam content 755 or less), marly loam sandy clay soil (silt content 75% or less)	0
	Clay, marly clay, humus	-2
	Peat, thick loam, marshy soil	-4
Ground water	None	0
	Exist	-1
	Vary	-2
Resistivity	10,000 ohm.cm or more	0
	10,000 - 5,000	-1
	5,000 - 2,300	-2
	2,300 - 1,000	-3
	1,000 or less	-4
Moisture content	20% or less	0
	20% or more	-1
pH	6 or more	0

	6 or less	-2
Sulphide and hydrogen sulphide	None	0
	Trace	-2
	Exist	-4
Carbonate	5% or more	+2
	5-1%	+1
	1% or less	0
Chloride	100 mg/kg or less	0
	100 mg/kg or more	+1
Sulphate	200 mg/kg or less	0
	200 -500 mg/kg	-1
	500 - 1000 mg/kg	-2
	1000 mg/kg or more	-3
Cinder and coke	None	0
	Exist	-4

Soil rating:	0 or above - Non-corrosive
	0 to -4 - Slightly corrosive
	-5 to -10 - Corrosive
	-10 or less - Highly corrosive

CORROSION CASE HISTORIES

While corrosion rates can be estimated using theoretical assessment, the one certainty is that in real life, the unexpected will always happen. For this reason, case history studies are very important for establishing performance benchmarks. Interest in the corrosion of steel buried structures has always been maintained, and a constant stream of information from a wide variety of sources is available.

There are two issues that determine the life of buried steel. The first is the life of the protective coating and the second is the corrosion rate of the steel. The item can be deemed to have failed when the steel loss is sufficient to prevent the steel performing its structural function.

Where polymer coatings are applied to buried steel items, most commonly pipelines, the failures are rarely caused by general deterioration of the coating. Localised failure due to holidays in the coating or pin holing or large-scale corrosion related to electrolysis are common causes of failure in these installations.

Metallic coatings, specifically galvanizing, and to a lesser extent aluminium, fail through progressive consumption of the coating by oxidation or chemical degradation. The rate of degradation is approximately linear, and with galvanized coatings of known thickness, the life of the galvanized coating then becomes a function of the coating thickness and the corrosion rate.

Steel corrosion can be assessed similarly, although the body of case history evidence indicates that corrosion rates of steel in soil decrease with time as corrosion products block access of the corrodants to the steel surface. Studies of steel piling corrosion in the USA in severe environments have shown initial corrosion rates exceeding 100 microns per year in the first two years of service, falling to an average of 50 microns per year over the first 20 years to stabilise at 25 microns per year after that.

BlueScope Steel has done extensive testing of its steel piles over a number of years and has drawn the following conclusions based on case history measurements of piles in Victoria:

Corrosion rate of steel in undisturbed soil/compacted fill	10-20 microns per year
Corrosion rates of steel in fill sites - low compaction	20-30 microns per year
Corrosion rates of steel in fill sites subject to tidal movement	30-50 microns per year.

CORROSION RATES AND AUSTRALIAN STANDARDS

The use of corrugated steel culverts has been long established in Australia. A standard has been developed and the most recent revision, AS/NZS 2041:1998, contains a significant amount of useful information in its Appendix C on durability issues.

There are a number of informative tables in this Standard that address corrosion issues for a variety of coatings as well as the base steel. These tables base corrosion rates on soil resistivity and pH as well as soil classifications. These tables nominate corrosion rates for galvanized coating from around 3 microns per year in well drained soils with neutral pH to over 20 microns per year in undrained acidic (pH<4) soils.

Metal loss for steel is nominated at less than 10 microns per year in well-drained soils with high resistivity and pH greater than pH5, to 300 microns per year in poorly drained soils with low resistivity (usually related to chloride concentration). Reasonable averages derived from these tables for both zinc and steel in contact with soil are for zinc, 6-10 microns per year, and for steel, 20-30 microns per year.

DETERMINATION OF PRODUCT LIFE IN-GROUND

In designing steel products for use in soil, there is enough information available to make reasonable estimates of service life of the structure. For products like screw-in piles used for house foundations, and lighting and power poles, these considerations are important in determining their service life.

Often, the focus is simply on the performance of the protective coating. However, an understanding of the steel's performance allows a better outcome through the provision of a corrosion allowance over and above the structural requirements of the steel.

Taking the example of a screw-in pile used as a house foundation, the steel thickness needed to support the structure is in the order of 2.5-3mm in a square or circular hollow section pier. By using a pier with a wall thickness of 4.5-5 mm, with a heavy duty hot dip galvanized coating with a minimum coating thickness of 85 microns, inside and out, the durability expectations would be as follows, in a normal domestic building site environment:

Galvanized coating life	85 micron coating/ 6 microns/year	= 12 years
Steel corrosion allowance	2 mm at 30 microns per yea	= 67 years
	TOTAL	= 79 years

CONCLUSION

The use of steel in in-ground structural applications is on the increase, as the benefits of using well-engineered steel alternatives are recognised by engineers and specifiers. Given an understanding of the corrosion issues involved, it is possible to engineer an acceptable life for these buried structures.

The option of using high performance coatings in conjunction with additional steel is a reliable method of ensuring a long service life for these installations.

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INDUSTRIAL GALVANIZERS

INGAL
SPECIFIERS MANUAL

01 - SPECIFIERS MANUAL — THIRD EDITION

Industrial Galvanizers Australian Galvanizing Division (IGAG) operates nine galvanizing plants around Australia, ranging in size from large structural galvanizing facilities to specialised small plants designed to process small parts.

The Australian Galvanizing Division has galvanized in excess of 2 million tonnes of steel products in Australia since its first plant was commissioned in 1965 and is recognized for its ability to handle complex and difficult projects, as well as routine contracts.

This experience has been collated in the Specifiers Design Manual, to assist those involved in the design of steel products and projects to better understanding the galvanizing process and allow the most durable and cost-effective solutions to be delivered to these products and projects. All sections of this Third Edition have been completely updated and additional sections have been included to provide additional technical information related to the use of hot dip galvanized steel.

In addition to its Australian Galvanizing operations, Industrial Galvanizers Corporation has a network of manufacturing operations in Australia, as well as galvanizing and manufacturing businesses throughout Asia and in the USA.

The company's staff in all these locations will be pleased to assist with advice on design and performance of hot dip galvanized coatings and products. Contact details for each of these locations are located elsewhere in this manual.

This edition of the Industrial Galvanizers Specifiers Manual has been produced in both html and .pdf formats for ease of access and distribution and all documents in the Manual are in .pdf format and can be printed if paper documents are required.

The Specifiers Manual is also accessible in its entirety on the company's web site at www.ingal.com.au.

Additional copies of the Specifiers Manual are available on CD on request.

PUBLISHER:
Industrial Galvanizers Australian Galvanizing Division,
PO Box 503, MOOROOKA
QLD 4105
Ph: 07 38597418

EDITOR:
John Robinson,
Mount Townsend Solutions Pty Ltd
PO Box 355, JESMOND NSW 2299
Ph: 0411 886 884
Email: mt.solutions@optusnet.com.au

LAYOUT AND DESIGN:
Adrian Edmunds,
Nodding Dog Design
Ph: 0402 260 734
Email: adrian@noddingdogdesign.com
Web: www.noddingdogdesign.com