44 - STEEL — ITS CORROSION CHARACTERISTICS

1. INTRODUCTION

Because steel is relatively easy to convert from its ores (oxides) to metal, it is just as keen to return from whence it came and go back to being iron oxide in one form or another. It is for this reason that for most applications, steel needs a protective coating to ensure its durability and aesthetic appearance. While the corrosivity of locations if often measured in terms of the corrosion rate of steel test panels, not all that much attention is given to the various types of steel and the stand-alone performance of steel in manufacturing and construction applications.

Poor quality paint systems can accelerate steel corrosion by concentrating pollutants and corrosion cells around andv8nder the paint film.

This review looks at the stand-alone performance of steel as there may be applications that do not require the use of costly protective coatings systems for many applications with short-to-medium term durability requirements.

2. STEELS AND STEELS

While any iron based product may be generically referred to as steel, there are an infinite variety of iron and steel products that have differing corrosion characteristics. For the purpose of this review, only those steel that are likely to be used in manufacturing or construction are considered. Special high strength steel, stainless steels and high-alloy steels are in categories of their own and are used for specialist applications.

Mill scale initially prevents steel from corroding but quickly breaks down into other iron oxides that accelerate the rusting process with unprotected steel.

The most common types of steel used in construction and manufacturing are:

1. Cast iron
2. Mild steel
3. Low alloy steel.

The chemistry of these different types of iron and steel influences their corrosion characteristics, so the following brief description of each type is included below.

2.1 CAST IRON

Cast irons include many metals having a wide variety of properties. Although cast iron is often considered a simple metal to produce and to specify, the metallurgy of cast iron is more complex than that of steel and most other metals.

Steels and cast irons are both primarily iron with carbon as the main alloying element. Steels contain less than 2 and usually less than 1% carbon; all cast irons contain more than 2% carbon. In addition to carbon, cast irons must also contain silicon, usually from 1 to 3%; thus, they are iron-carbon-silicon alloys.

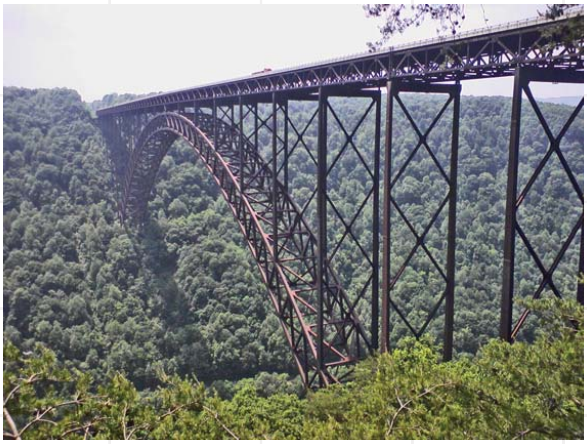
For each basic type of cast iron, there are a number of grades with widely differing mechanical properties. These variations are caused by differences in the microstructure of the metal that surrounds the graphite (or iron carbides). Two different structures can exist in the same casting. The microstructure of cast iron can be controlled by heat treatment, but once graphite is formed, it remains.

2.1.1 Gray iron: This is a supersaturated solution of carbon in an iron matrix. The excess carbon precipitates out in the form of graphite flakes. Impact strength of gray iron is lower than that of most other cast ferrous metals. In addition, gray iron does not have a distinct yield point (as defined by classical formulas)..

There are many instances where steel is used without a protective coating. Rail lines are a good example and have excellent durability in most Australian environments.

2.1.2 Ductile iron: Ductile, or nodular, iron contains trace amounts of magnesium which, by reacting with the sulfur and oxygen in the molten iron, precipitates out carbon in the form of small spheres. These spheres improve the stiffness, strength, and shock resistance of ductile iron over gray iron

2.1.3 White iron: White iron is produced by “chilling” selected areas of a casting in the mold, which prevents graphitic carbon from precipitating out. Both gray and ductile iron can be chilled to produce a surface of white iron, consisting of iron carbide, or cementite, which is hard and brittle and is used for abrasion resistant applications..



While not widely used in Australia, weathering steel has been used extensively in structural applications in the USA, with several thousand tonnes used on the New River Gorge Bridge in west Virginia.

2.1.4 Malleable iron: Malleable iron is white iron that has been converted by a two-stage heat treatment to a condition having most of its carbon content in the form of irregularly shaped nodules of graphite making it malleable and easily machined.

2.1.5 High-alloy irons: High-alloy irons are ductile, gray, or white irons that contain 3% to more than 30% alloy content. These irons are usually specified by chemical composition as well as by various mechanical properties. High-chromium irons (typically, about 16%), combine wear and oxidation resistance with toughness. Irons containing from 14 to 24% nickel are austenitic and they provide excellent corrosion resistance for no-nmagnetic applications. The 35%-nickel irons have an extremely low coefficient of thermal expansion and are also nonmagnetic and corrosion resistant.

2.2 Mild steel

In Australia, the chemistry of most standard grades of structural steel is covered in AS/NZS standards for the various types of steel products. AS/NZS 3697 deals with hot rolled bars and sections. AS/NZS 1594 covers hot rolled coil and flats, AS 1442 covers carbon and carbon manganese (forging and heat treatable) grades. Steels in this last classification are rarely used in structural applications.

These types of steels have carbon contents typically up to 0.25%, manganese levels around 1.5% and silicon levels that can vary quite widely depending on the steelmaking process and mechanical property requirements. Some micro-alloying elements such as copper, nickel, chromium and molybdenum may also be present in these steels.

Depending on the manufacturing process, the ex-mill steel sections may have greater or lesser degrees of mill scale adherent to their surfaces. Hot rolled angles, bars, channels and universal sections may have relatively heavy adherent mill scale, while hot rolled coil may have very little, or thin adherent mill scale.

2.3 Low alloy steels.

These steels typically contain 2-3% of alloying elements such as copper, nickel. chromium and phosphorous. These types of steels have better mechanical properties than the mild steel grades, but most importantly, they have better corrosion resistant properties because of the nature of the oxide film that form on their surfaces. Tightly adherent oxide films are formed on these steels that form a barrier to atmospheric corrodents

These types of steels are referred to as weathering steels and are have been used without any anti-corrosion coatings for many years in structural application. There are certain conditions that can affect their performance, one of the most important being that they need have good open air exposure. These steels have corrosion rates typically around 1/3 or less than those of mild steels.

In Australia, weathering steel has not been widely used for structural applications. It main use has been in transport applications such as truck bodies and rail wagons where abrasion makes the used of protective coatings impractical, or in architectural applications where the ‘rust’ colour of the steel is incorporated into the aesthetics of the building or structure.

BlueScope Steel is a local producer of weathering steels and it has produced technical data sheets on its weathering steel grades that highlight the special requirements associated with the use and fabrication of these types of steels.

These architectural elements on a harbour-side building in Newcastle, NSW are fabricated from uncoated weathering steel.

3. IRON AND STEEL CORROSION SYSTEMS

The fact that steel rusts through its reaction with oxygen in the presence of moisture is well established. Iron and steel are not homogeneous materials. As the micrographs accompanying this chapter illustrate, there is a matrix of pure iron (ferrite), iron carbides, other intermetallic compounds and, in cast iron, graphite.

On the metal’s surface, these components create a multitude of adjacent anodes and cathodes and the electrochemistry of corrosion will prosper on such a surface and the presence of moisture.
Most steel used for structural application is already substantially ‘rusted’ when it gets to the warehouse as it is coated with mill scale. The mill scale present on steel, arising from the hot rolling process, is typically about 50 microns thick and contains the three common oxidation states of iron; FeO (ferrous oxide) closest to the surface, Fe_3O_4 (magnetite) in the middle and Fe_2O_3 (ferric oxide) on the top.
Mill scale initially acts as a protective barrier to the steel, but soon its frangible and permeable nature allows corrodents to contact the steel surface and rapid localised corrosion can occur at the exposed sites.

The critical factors determining the atmospheric exposure rate of steel are; moisture (humidity or precipitation) and the presence of SO_2 (sulfur dioxide). Unlike on zinc coatings, sulfur dioxide is a far more important corrodent on steel than are chlorides, in that much lower levels of SO_2 will precipitate higher rates of steel corrosion.

The presence of moisture (water) on the steels surface and not its volume is the critical factor. Estimates of the amount of water on a metal surface have been made and are approximately as follows:

Critical relative humidity	0.01	g/m^2
100% Relative Humidity	1	g/m^2
At the Dew Point	10	g/m^2
Wet with rain	100	g/m^2

Low levels of surface moisture may, in fact, produce a more aggressive environment because any corrodents on the steel’s surface will form more highly concentrated electrolytes, while rain may dilute and remove any soluble surface contaminants.

The major driver of metal corrosion in Australia is chloride, and while chlorides are not critical in corrosion of steel at anything like the levels at which SO_2 has an impact, the sheer volume of chlorides generated in much of Australia's coastal regions make them a force to be reckoned with when steel corrosion has to be managed. Where high levels of airborne chlorides are present (oceanfront sites), steel corrosion rates can be extremely high, but this effect drops off rapidly with distance from ocean surf.

Estimated rates of steel corrosion related to the distance from ocean surf and in other environments are listed in Table 1.

Location	Steel Corrosion Rate – mm/year
50 m from ocean surf	0.20 – 0.50
200 m from ocean surf	0.10- 0.20
500 m from ocean surf	0.05
1 km from ocean surf	0.025
Coastal urban/metropolitan	0.025
Inland – East of Great Dividing Range	0.010 – 0.025
Inland – West of Great Dividing Range	<0.010

NOTE: The corrosion rates shown in Table 1 are influenced by factors such as orientation, height above ground level, local topography, regional climatic condition (ambient temperatures) and rainfall patterns.

4. BETTER BARE THAN BADLY COATED

When steel is painted, the paint acts as a barrier coating to prevent moisture and corrodents from contacting the steel's surface. Poorly applied paint coatings can be more damaging to steel than no coating at all. When the coating is breached, highly anodic areas are created around the edges of the failed coating. These areas produce high corrosion currents and resulting concentrated corrosion cells. These areas of high corrosion energy will progress along the edge of the paint film, undercutting it. Deep localised corrosion areas causing pitting, and in some cases, perforation, of the steel section can occur under these circumstances.

5. STAND ALONE STEEL

There are many instances where uncoated steel has demonstrated excellent durability without any coating applied to it, just as there are cases where corrosion can consume a substantial steel section in a relatively short time.

In the drier rural and desert areas of Australia, uncoated steel has a negligible corrosion rate. A good example is the humble star post, along with the uncoated wire, that was used in the 19th and early 20th Centuries to fence the entire continent.

Many of these installations are 100 years old and remain serviceable.

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.

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