CorTen® Steel

Technical Guide

March 2022

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Cor-Ten® Steel

The following information is intended as a brief technical reference guide to Cor-ten steel.

How Cor-ten Works

In the presence of water and air, all low alloy steels rust at various rates according to the amount of oxygen present in the atmosphere. With conventional steels, the rust layer becomes non-adherent and detaches from the metal surface – reducing the thickness of the material and consequently the effectiveness of the steel.

With Cor-ten steel, the process of rusting is initiated in the same way but the alloying elements used, e.g. chrome and copper etc., react to produce a 'patina' or (oxide film) which is much more dense and therefore adheres tightly to the base metal. As the oxidation process develops over time, the 'patina' impedes the access of oxygen and moisture to the metal surface, thus reducing the 'rusting process' considerably, giving increased performance to the steel.

The rapidity with which the steel develops its protective oxide film depends mainly upon the nature of the environment and exposure to the elements. In an industrial atmosphere, the weathering process will be quicker (particularly in the presence of sulphur), and the colour of the 'patina' darker than in a rural atmosphere.

Owing to the warming and drying action of the sun, metal surfaces exposed to the south and west (in the Northern Hemisphere) develop a smoother, more uniform 'patina' than those facing east and north. Higher temperatures permit more rapid conversion/dehydration of the corrosion products, whereas surfaces exposed away from the sun react more slowly; where the 'patina' may exhibit a somewhat granular texture.

Using Cor-ten Unpainted

Cor-ten is not a completely maintenance-free material. It should be inspected periodically according to its design and conditions of use to see that all joints and surfaces are performing satisfactorily. If necessary, maintenance is usually by cleaning with compressed air or water hosing to free dust and debris from the structure. Any surfaces not accessible for inspection and maintenance must be painted or coated.

- Cor-ten has been designed and manufactured to give excellent performance in particular and demanding applications. To obtain optimum performance from Cor-ten in the unpainted condition, the following points should be noted:

- To provide a sound, uniform surface for the formation of the protective 'patina', all exposed, unpainted Cor-ten surfaces (including welded areas) must be suitably prepared. The hot-rolled products should be blasted clean or pickled. Cold reduced and pickled sheets need only be cleaned to remove grease, oil or foreign products.
- Design features that could or will collect or retain water must be avoided such as pockets, crevices etc.
- Since any interruption in the surface can cause the oxide coating to develop unevenly, designers should consider the effect of the system construction, e.g. welding (see section on welding).

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- Moisture dripping from the steel, especially during the early years of exposure, will contain soluble iron salts which can stain or streak adjacent materials. This run off is particularly concentrated during the early years of 'patina' formation. This natural process in no way affects the performance of the steel. Designers have used gutters, pipes and dripping rims for the systematic drainage of this natural solution. Materials subject to minimal staining include glass, ceramic tile, glazed brick, porcelain coatings, washable air-drying and thermosetting organic coatings, extruded neoprene, and stainless steels. Materials subject to severe staining are concrete and stucco, galvanized steel, unglazed brick, matte porcelain enamels, stone, and wood.

- Damp debris on Cor-ten or contact with any materials which may retain moisture will accelerate corrosion.

- Interior surfaces of Cor-ten structures must be protected as though the material were ordinary-carbon steel.

- Unpainted Cor-ten is not suitable for severe marine or industrial environments.

- Applications which involve total submersion must be protected in a way which extends well above the ground line or high water line.

- Overlapping joints which may be subject to capillary action should be painted or sealed.

- Sealants that perform satisfactorily with Cor-ten are readily available.

- It may be necessary to paint Cor-ten which is in contact with other structural materials if galvanic reaction is a possibility.

- Materials used to mark Cor-ten for identification purposes should contain non-indelible compounds, or Cor-ten should be marked in areas that will be hidden after completion. Otherwise, marks will remain visible for many years unless blast cleaned after construction.

- The interior and all other unexposed surfaces of weather-resistant steel fascias can be prone to moisture accumulation from numerous sources including capillary action and condensation. The designer must therefore exercise great care in the detailing of such elements, ensuring that they are well ventilated and self-draining with no possibility of moisture entrapment.

Painting and Protection

In certain circumstances, which prevent the 'patina' forming, Cor-ten will require the same paint procedure as for carbon steel. It has been shown that Cor-ten prevents under-creep at areas of damage or degradation of the paint film. This will be beneficial as the areas of touch-up and repaint will not grow to any great extent, even after a prolonged period of time. Any damaged areas of bare metal will be protected by the subsequent forming of the protective oxide 'patina'.

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Environmental Considerations.

Cor-ten has been extensively used throughout the world where environmental considerations have been of prime importance such as the necessity to blend high strength steel structures with the natural environment. There are, however, a number of environments where Cor-ten cannot be used in its unpainted condition.

- In atmospheres where high concentrations of strong chemical or industrial fumes are present.
- Submerging in water or underground. In both cases, the performance will be the same as with carbon manganese steels.
- Conventional methods of protection such as concrete encasements, cathodic protection or a high quality paint system extended well above the water line and ground level can be used.
- Where the steel would be exposed to high concentrations or chloride ions which would occur from salt-water spray, salt fogs or airborne salts from a coastal environment.
- Salt adversely affects the 'patina' and because of its hygroscopic nature maintains a continuously damp environment on the metal surface.

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Fabrication

Cold Forming

Cor-ten steel sheet/plate can be formed using conventional means with good fabrication practices.
The higher strength of Cor-ten means that it is necessary to use slightly greater forming pressures with more liberal bending radii than those normally used for mild steel to accommodate increased spring-back.

For sheet and plate up to 6mm thick, the minimum recommended internal forming radius is twice the thickness of the material.

For plate from 6mm to 13mm thick, the minimum recommended internal forming radius is three times the thickness of the material.

Cutting

Flame cutting e.g. oxy-acetylene, oxy-propane or plasma arc cutting can be carried out using the same procedures as with high yield carbon manganese steels of similar CEV and thickness.
To avoid excessive hardening of the flame cut edges, and hence the danger of cracking; as a general rule, preheat temperatures similar to those of welding should be used.

Welding

Cor-ten has been used extensively in welded structures throughout the world. Cor-ten may be welded with the same facility as ordinary mild steel. However, its greater strength should be considered when selecting a welding procedure. For all welding procedures, appropriate minimum preheat temperatures should be used.

Although welding is straightforward, special procedures may be necessary to give matching weathering properties of the weld when the sheets/plates are to be used in exposed conditions.

In general, single pass welds can be carried out with carbon steel electrodes since there is usually sufficient pick-up of alloying from the parent material to give matching weathering characteristics. If multi-pass weld procedures are to be applied, special electrodes are required.

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High Temperature Applications

Although Cor-ten steel was not developed for high temperature applications, subsequent test data has shown that the elevated temperature properties of Cor-ten steel are superior to those of plain carbon structural steels.
Cor-ten A and, to a lesser extent, Cor-ten B have been used successfully in a number of non-critical applications that have not required specific pressure vessel alloy steels such as Cr-Mo.

Cor-ten A is of a greater interest than Cor-ten B for high temperature applications such as ductwork, chimneys and incinerators. Even in the absence of moisture at temperatures above 400°C, the 'patina' will still form.
At temperatures of about 425°C and higher, Cor-ten A exhibits much better elevated temperature ductility than Cor-ten B. Tension, creep, and creep rupture tests conducted on Cor-ten A steel containing 1% chromium showed that the steel exhibits attractive high temperature properties up to 540°C (1000°F).

Examination of oxidation behaviour shows that there is an improvement by some 50 degrees Celsius in oxidation resistance of Cor -Ten in the 500-700°C range for the same conditions. For example, under conditions which give 1mm/year oxidation loss on carbon or carbo/manganese steels, the temperature to give this loss on Cor-ten would be 50°C higher.

The precise improvement obtained with weather resistant steels is greatly dependent on the heating cycle experienced by the material and upon the environmental conditions prevailing.

NB. Cor-ten is not suitable for use in significant load bearing members above 450°C (approx.).

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Steel Corrosion Data

SOIL TYPE	SINGLE SIDED EROSION (mm)				
	INTENDED LIFESPAN				
	5 YEARS	25 YEARS	50 YEARS	75 YEARS	100 YEARS
Dense clean soils	0.00	0.30	0.60	0.90	1.20
Contaminated loose soil	0.15	0.75	1.50	2.25	3.00
Acidic soil	0.20	1.00	1.75	2.50	3.25
Very dense soil (e.g. clay)	0.18	0.70	1.20	1.70	2.20
Aggressive soil	0.50	2.00	3.25	4.50	5.75

Description

The above table displays corrosion data applicable to the Raaft range of steel edgings and planters. The values show the amount of mm that "disappear" over a set number of years (5, 25, 50, 75, 100). These numbers are based on flat standard construction steel sheet S235, in contact with damp soil on one side. The results for CorTen A steel will be equal or better.
Soil type is a key factor. The more aggressive the soil, the greater the levels of erosion.

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