



## Weather resistant COR-TEN

COR-TEN® A and COR-TEN® B are weather-resistant steel grades optimised through their alloying elements (copper, chromium, nickel and phosphorus) for a variety of environments and purposes.

When the total costs over the life cycle of structures are taken into account, significant economic benefits result from using these weathering steels.

Delivered as heavy plates, cut lengths, slit strips and coils, this product range is produced under licence from the United States Steel Corporation.

Cor-Ten is a registered trademark of USX Corporation.

### Applications:

- Chimneys
- Bridges
- Tubular bridges
- Façades
- Containers
- Tanks

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## Dimensions

Product shapes

- Heavy plates.
- Cut lengths, slit strips and coils.

Cut lengths with mill edges.

Steel grade	Thickness mm	Width mm	Length m
COR-TEN A	2-12	1 000 - 1 860	2-12
COR-TEN B	2-15	1 000 - 1 860	2-12

Maximum width of each steel grade depends on the thickness of the cut length.

Heavy plates.

Steel grade	Thickness mm	Width mm	Length m
COR-TEN A	6-12	1 901 - 3 300	2-15
COR-TEN B	6-40	1 901 - 3 300	2-15

Maximum length of each steel grade depends on the thickness.

The thickness ranges for heavy plates and cut lengths manufactured from weathering steel grades as per EN 10025-5 are the same as those of the approximately equivalent COR-TEN grades.

Steel grades and their approximate correspondence for weather resistance

Steel grade	EN 10025-5:2004
COR-TEN A	S355J0WP
COR-TEN B	S355J0W and S355J2W

For exact comparisons, original data sheets and standards must be used. The yield strength is guaranteed as  $R_{eL}$  for COR-TEN steels and as  $R_{eH}$  for the EN 10025-5:2004 weathering steel grades. A Charpy V impact test is carried out on standard steels equivalent to COR-TEN B.

## Tolerances

Plate products: EN 10029 Class A

Strip products: EN 10051

## Surface quality

Plate products: EN 10163-2 Class A3

Heavy plates are delivered in as rolled condition.

Cut lengths, slit strips and coils are delivered in as rolled condition or in pickled condition.

## Properties

The anticorrosive properties of weather-resistant steels are better than those of other structural steels in many applications. The enhanced weather resistance is based on the oxide layer, i.e. patina. The use of uncoated weather-resistant steel in steel structures saves surface treatment costs. The elegantly brown patinated surface is architecturally distinguished. Weather-resistant steel in flue gas structures prolongs the service life of chimneys and flue gas ducts.

## Materials testing

An inspection lot of COR-TEN steel grades at the steel works consists of a maximum of 40 tonnes of plates or coils from the same cast. One series of tests per inspection lot shall be carried out: a tensile test with transversal samples and, if required, a Charpy V impact test with longitudinal samples. Inspection and sampling of steel grades as per EN 10025-5:2004 shall be carried out in compliance with the standard.

## Mechanical properties

If agreed upon separately, COR-TEN B can be delivered with a guaranteed longitudinal impact strength of 27 J at the temperature of -20 °C, in which case it is marked with COR-TEN B-D.

### COR-TEN

	<b>Yield strength R<sub>eL</sub> N/mm<sup>2</sup> Minimum</b>	<b>Tensile strength R<sub>m</sub> N/mm<sup>2</sup> Minimum</b>	<b>Elongation A<sub>50</sub>% Minimum</b>
COR-TEN A	345	485	20
COR-TEN B	345	485	19

### EN 10025-5:2004

	<b>Yield strength R<sub>eH</sub> N/mm<sup>2</sup> Minimum Thickness mm</b>		<b>Tensile strength R<sub>m</sub> N/mm<sup>2</sup> Minimum Thickness mm</b>		<b>Elongation A<sub>80</sub>% Minimum Thickness mm</b>			<b>A<sub>5</sub> Minimum Thickness mm</b>
	<b>2-16</b>	<b>(16)-40</b>	<b>2-(3)</b>	<b>3-40</b>	<b>2</b>	<b>(2)-2.5</b>	<b>(2.5)-(3)</b>	<b>3-40</b>
S355J0WP	355	-	510-680	470-630	14	15	16	20
S355J0W	355	345	510-680	470-630	14	15	16	20
S355J2W	355	345	510-680	470-630	14	15	16	20

## Chemical composition

	<b>Content, % (ladle analysis)</b>									
	<b>C Maximum</b>	<b>Si</b>	<b>Mn</b>	<b>P</b>	<b>S Maximum</b>	<b>Al</b>	<b>V</b>	<b>Cu</b>	<b>Cr</b>	<b>Ni Maximum</b>
COR-TEN A	0.12	0.25-0.75	0.20-0.50	0.07-0.15	0.030	0.015-0.06	-	0.25-0.55	0.50-1.25	0.65
COR-TEN B	0.19	0.30-0.65	0.80-1.25	0.035 max.	0.030	0.020-0.06	0.02-0.10	0.25-0.40	0.40-0.65	0.40

The chemical composition of weathering steels as per EN 10025-5 complies with the standard.

## Carbon equivalent CEV

$$CEV = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

	<b>Thickness mm</b>	<b>CEV typical</b>	<b>Product</b>
COR-TEN A	2-12	0.35	Strip products
COR-TEN A	6-12	0.39	Plate products
COR-TEN B	2-15	0.38	Strip products
COR-TEN B	6-20	0.48	Plate products
COR-TEN B	(20)-40	0.50	Plate products

Carbon equivalents for grades as per EN 10025-5 are in line with the standard.

## The advantages of patina in different conditions

Thanks to their patina layer, weathering steels can be used in outdoor structures without any separate surface treatment. At its best, weather-resistant steel can save the costs of all the surface treatment and the repairs necessary later. The cost advantage in comparison to painted structures is emphasised in environments where regular repainting is required.

### Open air structures and patina

Weather resistance is based on the oxide layer, i.e. patina, which forms on the surface of the steel, and which, as a result of the alloying elements, is dense and nearly impervious to oxygen. Under normal weather conditions the patina will form in about 18-36 months, if the surface is alternately wet and dry. At first, the patina is a reddish brown colour, but with time takes on a darker hue.

In industrial environments, the patina forms more quickly and is darker in colour than in rural areas. In marine environments, the chlorides hinder the formation of the protective patina and they may prevent the intrinsic behaviour of COR-TEN steel. So, COR-TEN steel must not be used in the vicinity of sea or in areas where there is a high amount of chlorides in the air. For open air structures, the slow corrosion rate is taken into account by adding corrosion allowance to the nominal thickness.

### Example of corrosion allowance for untreated COR-TEN B steel

Type of atmosphere	Corrosion allowance to be added for one side of the nominal thickness for each 10-year period of working life	
	First 10 year period mm	Each following 10 year period mm
Rural	0.10	0.05
Urban <sup>1)</sup>	0.20	0.05
Industrial <sup>2)</sup>	0.20	0.10

1) With the chief impurity in the air being sulphur dioxide, SO<sub>2</sub>.

2) In addition to SO<sub>2</sub> the air also contains chloride. Also for locations in the immediate vicinity of salt water.

In order to ensure the uniform colour of the patina, all impurities must be cleaned from the steel surface. Organic impurities such as oil or protective greases must be removed by washing. Surface oxidation, oxides or rust can be removed by either shot-blasting or pickling. This will also accelerate the patina formation process. The surface of clean weathering steel can be pre-patinated by allowing the surface to get wet and dry.

### Indoor structures

The patina formed on structural parts which are not directly exposed to weather will not be as uniform as that on parts which are alternately made wet and dried. Small variations in colour may also occur on parts which are subjected to strong local variation in temperature. An example of this is a wall block under eaves.

### Submerged structures

Steel surfaces which are continually wet do not form a protective layer. These may be, for example, the surfaces of structures which are in contact with the ground or submerged in water. In these cases, it is recommended to paint the weather-resistant steel surface.

### Exposure to waste gases and high temperature conditions

Weather-resistant steels resist the corrosive effect of sulphur-containing stack gases very well, even better than stainless steel. Weather-resistant steels are at their best in construction, and are mainly used at temperatures above the dew point of sulphuric acid but are occasionally cooled down to temperatures below the dew point. These conditions prevail in many waste gas structures which cool down below the dew point during shutdowns.

The life expectancy of the weathering steel is extended under conditions of alternate wetting and drying. At temperatures constantly below the dew point an excessive amount of acid is condensed on the steel surface, which may be detrimental to the resistance to corrosion.

The special alloying of the steel, especially with chromium, improves in addition scaling resistance at high temperatures, even up to as high as 600-650 °C. However, when using weathering steels at temperatures over 425 °C, both the creep resistance requirements and, in phosphorus alloyed steel, possible thermal embrittlement of the material must also be taken into account.

### Painted structures

The surface of weather-resistant steel can be painted using the same methods applied in painting ordinary steels. As a result of the special alloying of the steel, a coat of paint can last twice as long as a coating on ordinary steel. If weather-resistant steel is continuously exposed to water, it is usually always recommended to be painted.

## Prefabrication services

The range of prefabrications available includes bending, shape cutting, precision cutting and bevelling.

### Cutting

Wide flats from plate and strip that are ready for assembly and dimensionally accurate speed up the manufacture of steel structures and assembly, and avoid wasting material. Thanks to the extensive range available, steel grades best suited for the application in question can be used.

Manufacture and the throughput time of installation will decrease using flat cut shapes. The customer will receive the needed components ready for installation, and can thus avoid unnecessary material and storing costs. If ordered, the products are delivered as shop-primed, bevelled and bent.

### Bevelling

Precision cut lengths and precision cut plates with a bevelled edge are components that can be delivered directly to the installation site, which saves time and reduces transport and storage costs. The dimensionally accurate groove ensures uninterrupted automated welding and fitting.

### Bent plate products

Bent plate products are components that are ready to be delivered to the installation site, which is beneficial in terms of schedule as well as transport and storing costs. If needed, the products can also be ordered as shop-primed, furnished with welding bevels, and cut to shape. Premarked matchmarks facilitate installation.

## Processing instructions

### Welding

Weathering steels can be welded under workshop conditions using all the common welding processes. Low-hydrogen welding procedures and consumables are recommended. Before welding, the patina must be removed, down to the bare steel, from the steel surface over a band of approximately 10–20 mm wide along the welded joint. It is also equally important to remove any moisture, grease, oil and other impurities from the surface.

### Working temperature

The carbon equivalent values are slightly higher in weathering steel than in S355 structural steel, which increases the preheating need correspondingly. In practice this difference applies only to COR-TEN B and the corresponding steels because, thanks to their lower material thickness, steel grades alloyed with phosphorus do not usually require an elevated working temperature. When welding those steels, it is recommended that for plates of over 15 mm thickness the working temperature should be increased to 100-200°C. In multi-pass welding the temperature between different passes must not exceed 200°C in order that the toughness of the heat affected zone (HAZ) remains good.

### Choice of welding consumables

- The weather resistance of welded joints can be ensured by using filler materials corresponding to the alloying of the base material.

- The mechanical properties of the welded joint have to be at least equivalent to those of the base material. Unnecessary over-strength is to be avoided as an increase in strength also increases residual stress.
- The impact strength of the welded joint must meet the set requirements, which are usually the same as those.
- If the base and filler materials mix sufficiently to provide good weathering resistance, ordinary non-alloyed consumables can be used. Sufficient mixing is achieved in single run welding of under 4 mm plates for butt joints, and for fillet welds with a design throat thickness of up to approximately 4 mm.
- Generally there is a small colour difference between a non-alloyed consumable material used in a weld and the weathering steel base material.
- In the multi-run welding of thick plates at least the final runs should be made using weathering consumables if the weld metal is also intended to be weather-resistant.
- Welding consumables of sufficient deformation capacity must be used for the sealing and root runs.
- Low-hydrogen consumables must be used, stored and dried in accordance with the manufacturer's instructions.

## Forming

Weathering steels can be cold-formed in the same manner as S355 structural steels. The table [table 6] shows the smallest allowable bending radii to be used for flanging. Successful forming requires good workshop technology from the producer of the steel product. Worn tools, insufficient lubrication, surface defects on plates, and cutting burrs may all reduce the quality. Shot-blasting may also be unfavourable. Plates stored outside under cold conditions must be taken inside to warm up sufficiently before being formed. The formability of EN 10025-5:2004 weathering steels is in accordance the standard.

	Thickness mm											
	(2)-3	(3)-4	(4)-5	(5)-6	(6)-7	(7)-8	(8)-10	(10)-12	(12)-14	(14)-16	(16)-18	18-20
Smallest allowable internal bending radius mm												
COR-TEN A	6	8	10	12	21	24	30	36	42	-	-	-
COR-TEN B	6	8	10	12	21	24	30	36	42	48	54	60

Values apply to all forming directions.

## Heat treatment

Weathering steel applications do not normally require post-weld heat treatment. If, however, this is required by the customer or the authorities, it is recommended that stress relieving or normalising is carried out in accordance with the table below.

Heat treatment	Temperature °C	Treatment time Manner of cooling
Stress relieving	550-600 (target 580)	2 minutes / millimetre thickness, minimum 30 minutes. Slow cooling in the furnace.
Normalising	860-940 (target 910)	1 minute / millimetre thickness, minimum 15 minutes. Free cooling in air atmosphere outside the oven.

## Cutting

Weathering steels can be cut thermally and mechanically in almost the same manner as the S355 structural steels. When flame cutting thick plates, the working temperature recommendations concerning welding can be used as a guideline. Due to thin plate thickness CORTEN® A and corresponding steels do not normally need an elevated working temperature for thermal cutting. Slowing down the cutting speed and increasing the working temperature have a similar effect on cutting: the cooling rate of the cutting point decreases and so does the risk of thermal cracks. When handling weathering steels, it should be remembered that a plate taken directly from cold outside storage needs adequate time to warm up before mechanical cutting.

## Order & delivery

### Delivery conditions

**Heavy plates:** Hot-rolled, normalised rolled or normalised in furnace.

**Cut lengths, slit strips and coils:** Controlled rolled or thermomechanical rolled.

### Inspection documents

The inspection document shall be specified at the time of order. The European types of inspection documents are defined in the EN 10204:2004 standard.

### General delivery information for hot-rolled steels

General delivery information for hot rolled steels can be found from documents *Markings and packing*, *Ultra-sonic testing* and *General terms of sale*.