Hot rolled Steel Plates, Sheets and Coils

Structural steel

Weather resistant structural steels EN10025-5 and COR-TEN®

The anticorrosive properties of weather resistant steels are better than those of other structural steels in many applications. Weather resistant steels are self-protecting: the rust layer on the surface becomes a tight oxide layer that slows down the progress of corrosion. These steels are economical, long-lasting and fully recyclable materials.

Applications

- chimneys
- bridges
- tubular bridge
- façades
- containers
- tanks

Ruukki is a metal expert you can rely on all the way, whenever you need metal based materials, components, systems or total solutions. We constantly develop our product range and operating models to match your needs.

The corrosion properties of weathering steels are, in many applications, better than those of other structural steels. However, the steel is not stainless, on the contrary. Slowly with time the steel becomes patinated, as a result of which rusting slows down. In this way weathering steels are self-protecting and economic. Weather resistant steels are economical, long-lasting and fully recyclable materials.

- **Description of the steel grades**
  Ruukki markets weathering steels under the United States Steel Corporation's trademarks COR-TEN® A and COR-TEN® B and as grades in accordance with the EN 10025-5:2004 standard, table 1. Their weather resistance is based mainly on the effects of the alloying elements copper, chromium and nickel. In addition, phosphorus is alloyed in the COR-TEN® A and S355J0WP grades. If agreed upon separately, the COR-TEN® B grade can be supplied with guaranteed impact strength at a temperature of –20°C, in which case its designation is COR-TEN® B-D.

- **Applications in accordance with the steel grades**
  In many applications there are strong economic reasons for using weathering steels, when the total life cycle costs of the structures are taken into account at the design stage. Of the weathering steels the phosphorus alloyed grades COR-TEN® A and S355J0WP are best suited for atmospheric conditions and stack gas applications. Alternatively the steel grades COR-TEN® B and S355J0W can be used in this type of applications made from thin materials. It must be noted that phosphorus alloyed steels are not recommended for use in load-bearing structures. For load-bearing or heavy structures and also for low temperature applications the choice of impact strength tested grades is justified. Recommended grades are S355J2W and COR-TEN® B-D.

- **Product shapes**
  Weathering steels are manufactured both as plate products and strip products. Plate products include heavy plates and prefabricated products. The range of prefabrications available includes bending, profile cutting, precision cutting and bevelling. Strip products include cut lengths, slit strips and coils. The most common delivery forms are heavy plates and cut lengths.

- **Delivery conditions**
  Plate products: hot rolled, normalised rolled or normalised in furnace.
  Strip products: controlled rolled or thermomechanically processed.

- **Mechanical properties**
  The mechanical properties are shown in table 2.

- **Chemical composition**
  The chemical compositions of COR-TEN® steels are shown in table 3. The chemical composition of weathering steels as per EN 10025-5 complies with the standard.

- **Dimensions**
  The thickness ranges of heavy plates and cut lengths are shown according to steel grades in table 2. Other dimensions of weathering steels are laid down in the general production programme, including heavy plates, cut lengths, slit strip and coils manufactured from steel grades of the yield strength class 355 MPa.

- **Dimensional and shape tolerances**
  Plate products: EN 10029 Class A
  Strip products: EN 10051

- **Surface quality**
  Plate products: EN 10163-2 Class A3

- **Materials testing**
  An inspection lot of COR-TEN® steel grades at the steel works consists of max. 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 (KV) with longitudinal samples. Inspection and sampling of steel grades as per EN 10025-5:2004 shall be carried out in compliance with the standard.

- **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.

- **Corrosion properties**
  Weathering steel can be used in many structures without the need for further surface treatment as it is self-protecting. At its best weathering 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 situations where conditions are such that regular repainting is required.

  Open air structures and the conditions for atmospheric corrosion resistance
  Weathering steels resist atmospheric corrosion significantly better than normal structural steels. This so called 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 becomes a darker hue. In an industrial atmosphere the patina forms more quickly and is darker in colour than in rural areas. In a marine atmosphere the formation of the protective patina is prevented due to chloride exposure. For open air structures the slow advancement in corrosion is taken into account of by increasing the nominal thickness to include a corrosion allowance, table 4. An added bonus to be mentioned is that once the protective patina is formed further corrosion is almost non-existent. That is, corrosion progress in weathering steels is non-linear.

In order to ensure the uniformity of colour of the patina, all impurities must be cleaned from the steel surface. Organic impurities such as oil or protective greases should 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 or to use suitable acid solutions. It is recommended that marking should be carried out using chalk or other water-soluble means.

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

Exposure to waste gases and high temperature conditions
Weathering steels resist the corrosion effect of sulphur-containing stack gases very well, even better than stainless steel. Weathering steels are at their best in construction, which are mainly used at temperatures above the dew point of sulphuric acid but are occasionally cooled down into 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 of 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 be also taken into account.

Painted structures
The surface of weathering 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 weathering steel is continuously exposed to water, it is usually always recommended to be painted. An advantage of using weathering steel in wet conditions is that it, in case of local effects on paint coating, corrosion on the spot progresses more slowly than common steel.

- **Carbon equivalent**
  Carbon equivalents for the COR-TEN® steel grades are shown in table 5. Carbon equivalents for grades as per EN 10025-5 are in line with the standard.

- **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® A 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 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) will remain 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 increases residual stress too.
- The impact strength of the welded joint must meet the set requirements, which are usually the same as those of the base material.
- 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 4mm 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. 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.

- **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 7.

- **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 COR-TEN® A and corresponding steels do not normally need an elevated working temperature for thermal cutting. Slowing down the cutting speed and enhancement the working temperature have a similar effect on cutting: the cooling rate of cutting point decreases and so does the risk of thermal cracks. When handling weathering steels it is to be remembered that a plate taken directly from cold outside storage needs adequate time to warm up before mechanical cutting.

Steel grades and their approximate correspondence for weather resistance

Table 1

COR-TEN®	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 for COR-TEN® steels and as R_{eH} for weathering steel grades according to EN 10025-5:2004.
A Charpy V impact test is carried out on standard steels equivalent to COR-TEN® B.

Mechanical properties and thickness ranges COR-TEN®

Table 2

	Thickness mm		Yield strength R_{eL} N/mm²	Tensile strength R_m N/mm²	Elongation A_{50} %
	Strip products	Plate products	Minimum	Minimum	Minimum
COR-TEN® A	2 – 12	6 – 12	345	485	20
COR-TEN® B	2 – 13	6 – 40	345	485	19

EN 10025-5:2004

	Yield strength R_{eH} N/mm² Minimum Thickness mm		Tensile strength R_m N/mm² Minimum Thickness mm		Elongation A_{80} % Minimum Thickness mm			A_5 Minimum Thickness mm
	2 –16	(16) – 40	2 – (3)	3 – 40	2	(2) – 2,5	(2,5) – (3)	3 – 40
S355J0WP	355	–	510 – 680	470 – 630	14	15	16	20
S355J0W S355J2W	355	345	510 – 680	470 – 630	14	15	16	20

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.

Chemical composition

Table 3

	Content, % (ladle analysis)									
	C	Si	Mn	P	S	Al	V	Cu	Cr	Ni
	Maximum				Maximum					Maximum
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

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

Table 4

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 [1)]	0.20	0.05
Industrial [2)]	0.20	0.10

[1)] *With the chief impurity in the air being sulphur dioxide, SO_2.*
[2)] *In addition to SO_2 the air also contains chlorine. Also for locations in the immediate vicinity of salt water.*

Carbon equivalent CEV

Table 5

	Thickness mm	CEV typical	Product
COR-TEN® A	2 – 12	0.35	Strip products
COR-TEN® A	6 – 12	0.39	Plate products
COR-TEN® B	2 – 13	0.38	Strip products
COR-TEN® B	6 – 20	0.48	Plate products
COR-TEN® B	(20) – 40	0.50	Plate products

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

Formability

Table 6

	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

Table 7

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.

Our Customer Service is happy to give you further information

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