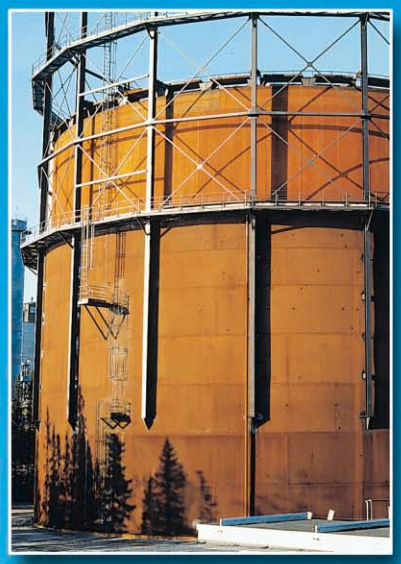
WEATHERING STRUCTURAL STEELS

for self protecting surfaces

COR-TEN and EN 10155



TRIM SURFACES AND COST SAVINGS WITH WEATHERING STRUCTURAL STEELS

In comparison with ordinary structural steels, weathering steels, in the unpainted condition, have markedly enhanced resistance to the corrosion stress caused by changeable atmospheric conditions. The corrosion resistance of these steels is based on their chemical composition, which has been formulated so as to develop a stable non-porous oxide layer on the surface of the steel.

Structures made of weathering steel need no surface treatment. The slow propagation of corrosion can be taken account of in the structural design.

COR-TEN – with ready-made surface finish

When the life-time maintenance cost of the steel structure is the main criteria, the use of weathering steel is often the most cost-efficient choice.

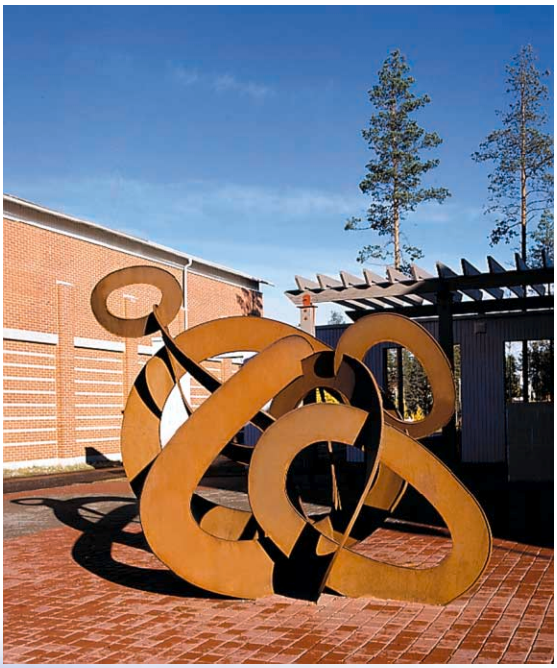
In the construction phase
– all the costs of surface treatment are saved
– throughput times at the workshops are shorter
– lifting and transport involve no risk of damaging the coating
– there is no need for the usual touch-up painting after erection.

In comparison with a painted structure, the saving in maintenance costs is even greater under conditions where repeated repainting is normally required. For example, pipeline bridges in an industrial atmosphere are extremely difficult to clean and paint after installation.

A natural and impressive COR-TEN façade

Cor-Ten is a truly ecological material. In most applications, Cor-Ten steel does not need to be coated. This reduces both the lifetime environmental load and the lifetime cost of steel. In addition, Cor-Ten is a 100-percent recyclable material.

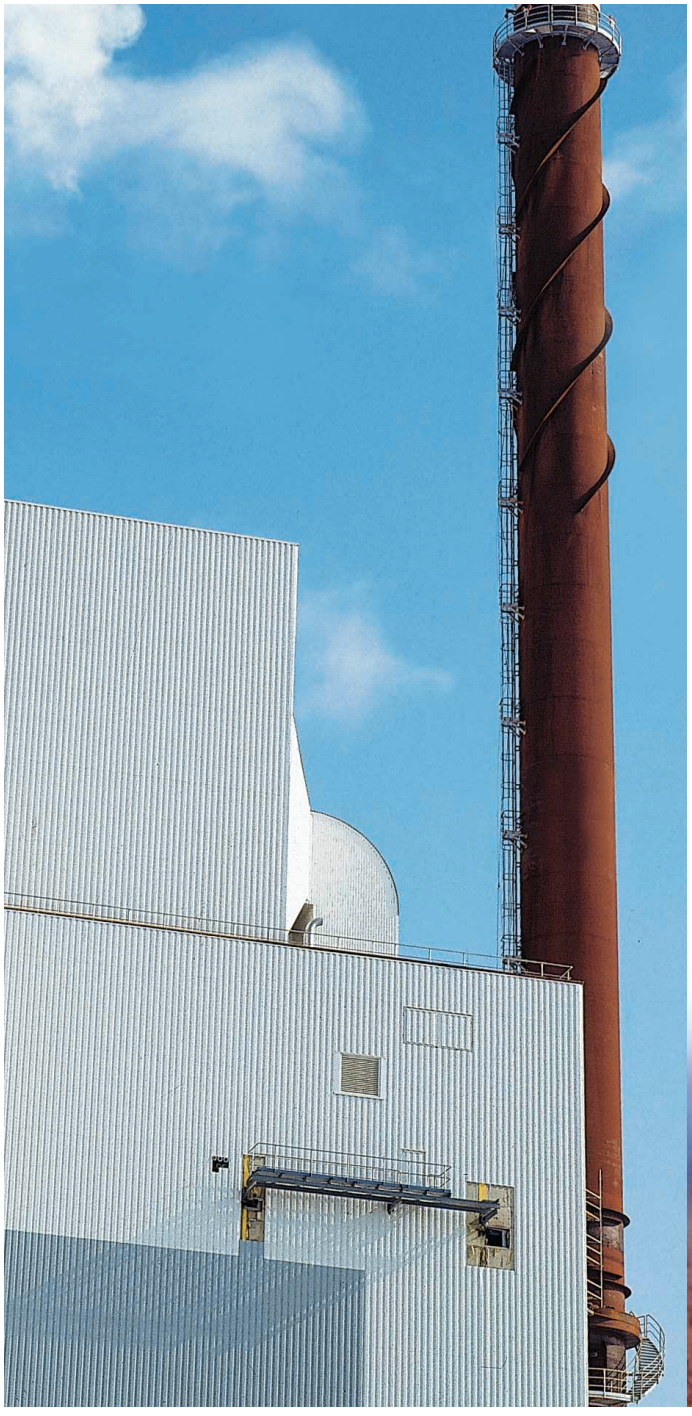
Cor-Ten steel develops the best patina when exposed to outdoor air under different weather conditions. Cor-Ten steel can be well combined with other materials. For detailed information about possible applications, see the 'Cor-Ten Façades' manual.



Weathering steel in a flue gas atmosphere

Under suitable conditions the sulphur oxides carried by flue gas can condense, as sulphuric acid, onto the surrounding surfaces. In flues and chimneys, where condensation of sulphuric acid occurs sporadically, weathering steels have been found to stand up very well to chemical stress. They have attained, therefore, a strong position as a material for steel chimneys and central heating furnaces.

Several research projects have shown that weathering steels have higher resistance to flue gases compared to general structural steels and, in some cases, even to stainless steels.



The special alloying formula (with Cr, Ni, Cu) of weathering steel improves its corrosion resistance under sulphuric acid dew point conditions and its resistance to scaling at high temperatures up to 600 – 650°C.

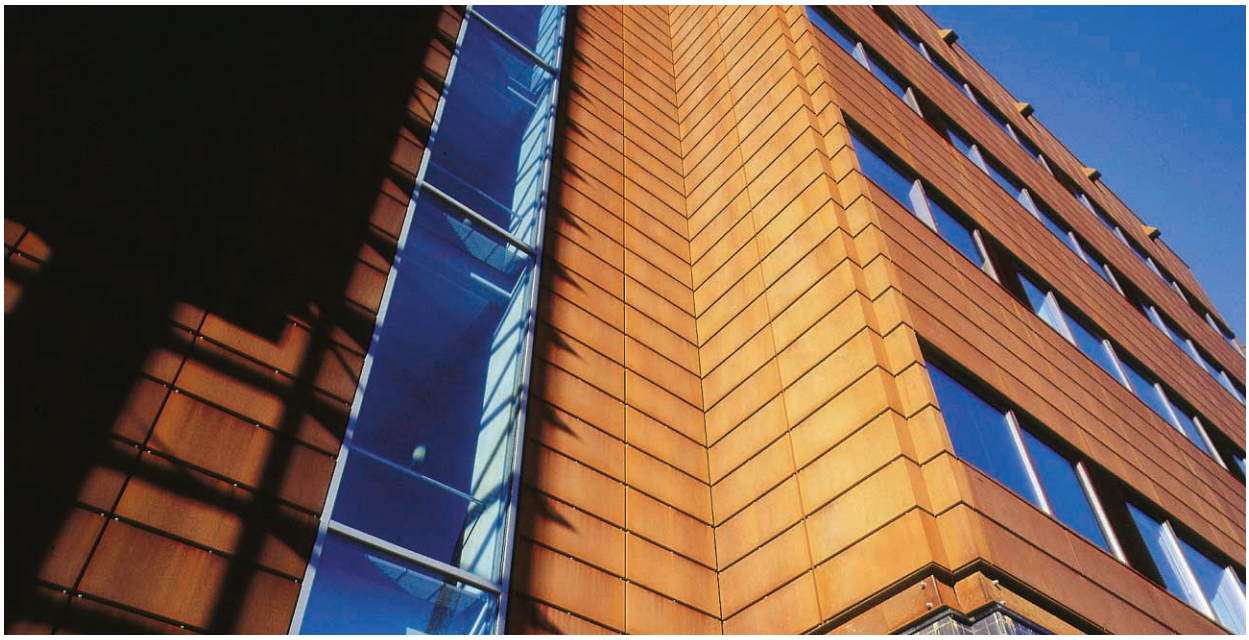
Weathering steel in the painted condition

Weathering steel products are commonly used in the painted condition for constructions such as steel boats and freight containers for sea transport. In continuous contact with water, the corrosion rate hardly differs from that of general structural steels, but the paint life on weathering steels can be up to twice as long. This is because the propagation of corrosion under local damage on painted surfaces is markedly slower than on ordinary steel. In this way, the appearance of painted structures remains trim much longer and the lifetime cost of shot blasting and repainting is halved.

COR-TEN A

GENERAL STRUCTURAL STEEL

The condition of specimens with a painted and scratched surface after a two-year exposure to a corrosive environment. It can be seen that undercutting of the paint layer has not proceeded in the CORTEN A specimen as it has in the ordinary steel specimen.



WEATHERING STEEL ACCORDING TO INTENDED USE

The selection of steel

NES Architectural offers weathering steels to both Standard EN 10155 and under the brand name COR-TEN. The steel grades S355JOWP, S355J2JOWP and COR-TEN A have the best weathering properties. Because of the phosphorus used as an alloying element, however, the impact strength of these steel grades is lower than that of other weathering steels. These weathering steels are best suited for sheet steel structures that are not under the risk of brittle fracture.

Typical applications for weathering structural steels include

- external wall claddings of buildings, weather strips
- chimneys and other structures under fl ue gas conditions
- transport tanks
- freight containers
- bridges
- heat exchangers
- similar other steel structures.

When the risk of brittle fracture has to be taken into consideration in the design because of high material thickness, low service temperature or for other reasons, it is better to choose another EN 10155 steel or COR-TEN B. Then the impact strength requirements for hot rolled steel can be agreed upon as for general structural steels.

At temperatures above 540°C, S355J0WP, S355J2WP, COR-TEN A and COR-TEN B have a clearly higher resistance to scaling than general structural steels. Research has shown that the resistance to scaling is rather good at a stable temperature up to 650°C, but reduces, if the temperature keeps changing considerably. In the latter case, it is recommended that the peak temperature should be 540°C. In terms of resistance to scaling at high temperatures, the best weathering steel is COR-TEN High Temp.

TECHNICAL CHARACTERISTICS

Corrosion

Conceptually, corrosion refers to the chemical or electrochemical degeneration of construction materials under environmental impacts. Corrosion is a characteristic of each material. In the case of steel, we generally speak of rust. The rusting behaviour of steel depends on its chemical composition, the environment, structural considerations and an appropriate design of the construction. In order to control the corrosion behaviour, weathering steels are alloyed with small amounts of chromium, nickel, copper and phosphorus. The environment, too, has a signifi cant effect on the corrosion behaviour.

When the surface of weathering steel is exposed to outdoor air, the oxygen and moisture in the air produce a compact oxide layer, patina, developing on the surface, thus preventing the further propagation of corrosion. The graph in Fig. 1 illustrates the difference between the corrosion rates of general structural steels and weathering steels.

Forming

Weathering steels can be cold formed the same as general structural steels of the corresponding grades. For strip rolled products, bending with the axis transverse to the major rolling direction is preferred. The suggested minimum bending radii for bending longitudinal to the rolling direction are given in Table 3. For applications calling for better forming properties, steels in accordance with Standard EN 10155 can be supplied with guaranteed fl angeability, or the COR-TEN AF grade can be used. Exacting forming operations are easier to carry out either by warm forming at a temperature under 600°C, or by hot forming at 800 – 1050°C.

Welding

Weathering steels are suitable for welding by all welding procedures. Elevated working temperatures are not needed when using dry welding consumables under favourable conditions. Although the recommended working temperature for welding weathering steels of over 15 mm thickness is 100 – 200°C, this preheating can be omitted in the case of steel grades S235J0W and S235J25W of any thickness. Capacitor Discharge (CD) stud welding can be used with copper coated steel studs, TIG welding with a corten welding wire is used to form a weld that oxidised in a similar manner. MIG welding for speed or to form a stitch weld for a structural application.

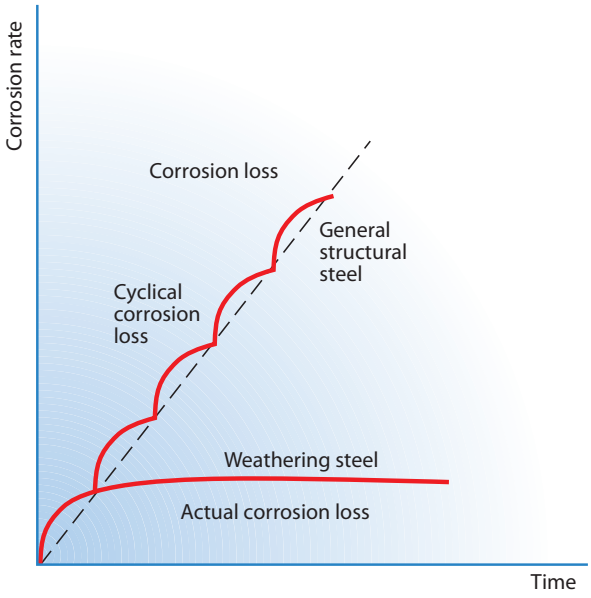


Figure 1.
The difference between the corrosion rates of general structural steel and weathering steel. Cyclical corrosion loss represents the change in weight/reduction of thickness which occurs when a protective oxide layer fails to develop: the steel oxidises – the rust layer protects – wears off – the steel surface oxidises again, etc. In weathering steel, the initial corrosion rate remains high until the protective oxide layer prevents further oxidation. The actual corrosion loss is low.

Testing and inspection documents

All weathering steels are provided with an inspection document in accordance with EN 10204 as specifi ed in the order.

Supply condition

All hot rolled weathering steels are supplied in the hot rolled condition except for COR-TEN B-D steel, for which the impact strength requirement is KV 27J/-20°C and the supply condition is, as normalised. Cold rolled weathering steels are supplied in the annealed and temper rolled condition and oiled for surface protection, unless otherwise agreed in connection with the order.

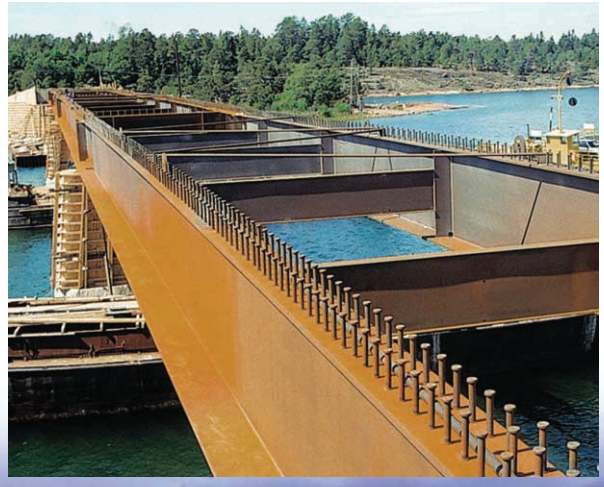


Table 1.

CHEMICAL COMPOSITION, EN 10155

Steel grade	C ≤ %	Si ≤ %	Mn %	P %	S ≤ %	Cr %	Cu %	Ni %	Al %
S235J0W [1]	0.13	0.40	0.20 – 0.60	≤0.040	0.040	0.40 – 0.80	0.25 – 0.55	0.65	0.020
S235J2W					0.035				0.020
S355J0WP	0.12	0.75	≤1.0	0.06 – 0.15	0.040	0.30 – 1.25	0.25 – 0.55	0.65	0.020
S355J2WP					0.035				0.020
S355J0W	0.16	0.50	0.50 – 1.50	≤0.040	0.040	0.40 – 0.80	0.25 – 0.55	0.65	0.020
S355J2G1W				≤0.035	0.035				0.020
S355J2G2W				≤0.035	0.035				0.020
S355K2G1W				≤0.035	0.035				0.020
S355K2G2W				≤0.035	0.035				0.020

The steel must contain at least one of the following alloying elements: Al total >0.020%, Nb = 0.015 – 0.060%, V = 0.02 – 0.12%, Ti =0.02 – 0.10%.
[1] As cold rolled, the steel grade is supplied with the marking RACOLD S235W.

Table 2.

MECHANICAL PROPERTIES, EN 10155

Steel grade	Yield strength minimum R_{eH}, N/mm²					Tensile strength R_m, N/mm²		Elongation minimum %					
	Nominal thickness, mm					Nominal thickness, mm		Nominal thickness, mm $L_0 = 80$ mm			Nominal thickness, mm $L_0 = 5{,}65\sqrt{S_0}$		
	≤16	>16 ≤40	>40 ≤63	>63 ≤80	>80 ≤100	<3	≥3 ≤100	>1,5 ≤2	>2 ≤2,5	>2,5 <3	≥3 ≤40	>40 ≤63	>63 ≤100
S235J0W [1] S235J2W	235	225	215	215	215	360 – 510	340 – 470	17	18	19	24	23	22
S355J0WP S355J2WP	355	–	–	–	–	510 – 680	490 – 630	14	15	16	20	–	–
S355J0W S355J2G1W S355J2G2W S355K2G1W S355K2G2W	355	345	335	325	315	510 – 680	490 – 630	14	15	16	20	19	18

Tensile tests are carried out in the transversal direction to rolling.
[1] As cold rolled, the steel grade is supplied with the marking RACOLD S235W.

Table 3.

FORMABILITY, EN 10155

Steel grade EN 10027-1 [2]	Direction of bending [1]	Minimum recommended inside bending radius with nominal thicknesses												
		≥1.5 ≤2.5	>2.5 ≤3	>3 ≤4	>4 ≤5	>5 ≤6	>6 ≤7	>7 ≤8	>8 ≤10	>10 ≤12	>12 ≤14	>14 ≤16	>16 ≤18	>18 ≤20
S235J0W [3]	t	2,5	3	5	6	8	10	12	16	20	25	28	36	40
S235J2W	l	2,5	3	6	8	10	12	16	20	25	28	32	40	45
S355J0W S355J2G1W S355J2G2W S355K2G1W	t	4	5	6	8	10	12	16	20	25	32	36	45	50
S355K2G2W	l	4	5	8	10	12	16	20	25	32	36	40	50	63

[1] t = bending direction transversal to the rolling direction, l = bending direction longitudinal to the rolling direction
[2] EN 10027-1 and 2
[3] As cold rolled, the steel grade is supplied with the marking RACOLD S235W.

Table 4.

CHEMICAL COMPOSITION, COR-TEN

Steel grade	C ≤ %	Si %	Mn %	P %	S ≤ %	Cr %	Cu %	Ni ≤ %	V %	Al % [1]
COR-TEN A [2]	0.12	0.25 – 0.75	0.20 – 0.50	0.07 – 0.150	0.030	0.50 – 1.25	0.25 – 0.55	0.65	–	0.015 – 0.060
COR-TEN AF	0.12	0.25 – 0.75	0.20 – 0.50	0.07 – 0.150	0.020	0.50 – 1.25	0.25 – 0.55	0.65	–	0.015 – 0.060
COR-TEN HIGH TEMP	0.12	0.25 – 0.75	0.20 – 0.50	0.07 – 0.150	0.030	0.75 – 1.25	0.25 – 0.55	0.40	≥0.02	0.020 – 0.060
COR-TEN B	0.19	0.30 – 0.65	0.80 – 1.25	≤0.035	0.030	0.40 – 0.65	0.25 – 0.40	0.40	0.02 – 0.10	0.020 – 0.060

[1] The steel must contain at least one of the following alloying elements: Al total >0.020%, Nb = 0.015 – 0.060%, V = 0.02 – 0.12%, Ti =0.02 – 0.10%.
When two ore more alloying elements are used at the same time, at least one of the minimum requirements has to be met.
[2] As cold rolled, the steel grade is supplied with the marking RACOLD COR-TEN A

Table 5.

MECHANICAL PROPERTIES, COR-TEN

Steel grade	Thickness, mm	Mechanical properties at room temperatures				
		Yield strength minimum (R_{eL}) N/mm²	Tensile strength minimum (R_m) N/mm²	Elongation minimum (A_{50}) %	Impact strength longitud., minimum	
					t, °C	KV, J
COR-TEN A	2 – 13	345	485	20	–	–
COR-TEN A [1]	1 – 3	310	450	22	–	–
COR-TEN AF	2 – 13	345	485	20	–	–
COR-TEN HIGH TEMP	2 – 13	345	485	18	–	–
COR-TEN B	2 – 60	345	485	19	–	–
COR-TEN B-D	2 - 60	345	485	19	-20	27

Tensile tests are carried out in the transversal direction to rolling.
[1] As cold rolled, the steel grade is supplied with the marking RACOLD COR-TEN A.

Table 6.

FORMABILITY, COR-TEN

Steel grade	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	>20 ≤60
	Minimum permissible inside bending radius												
COR-TEN A [1]	4	8	10	12	21	24	30	36	42	–	–	–	
COR-TEN AF	3	5	6	8	10	12	15	18	25	–	–	–	
COR-TEN B	4	8	10	12	21	24	30	36	42	48	54	60	6 x t

[1] As cold rolled, the steel grade is supplied with the marking RACOLD COR-TEN A. Bending test 180°, 1 t, t = thickness, mm.

Table 7.

COMPARISON BETWEEN COR-TEN STEELS AND EN 10155 STANDARD STEELS

COR-TEN	EN 10155
–	S235J0W
–	S235J2W
COR-TEN A JA AF	S355J0WP
COR-TEN A JA AF	S355J2WP
–	S355J0W
COR-TEN B–D	S355J2G1W
COR-TEN B–D	S355J2G2W
–	S355K2G1W
–	S355K2G2W

For accurate comparisons, the original standards are to be used.