DOMEX
DOCOL

Corrosion resistant steels

SSAB
TUNNPLÅT

Corrosion resistant steels develop their own atmospheric protection

The corrosion resistant steels produced by the SSAB Tunnplåt steelworks in Borlänge are available with minimum yield strengths ranging between 355 N/mm² and 700 N/mm².

In the open, corrosion resistant steels initially corrode just like ordinary carbon steels. But after a time, a uniform, dense oxide layer (patina) is formed on the steel surface. This is due to the suitably formulated content of Cu, Cr, P and Si in the steels. The oxide layer adheres firmly and prevents moisture from penetrating through it and causing continued corrosion. Corrosion resistant steels thus develop their own effective atmospheric protection against corrosion that reduces the corrosion attack over, say, 10 years to less than half of that sustained by plain carbon steel.

Typical applications for corrosion resistant steels include heavy steel structures and containers for which high strength and anti-corrosion properties can result in a simpler design and reduced maintenance or none at all. The material offers great benefits for industrial chimneys, both externally and in the flue gas passages. This is because the corrosion resistant steels are well able to withstand a sulphurous environment.

Product range

DOMEX W and DOCOL W

In addition to having good corrosion resistance, Docol W and Domex W corrosion resistant steels from SSAB Tunnplåt are also characterized by good formability, weldability and impact strength.

Thinner corrosion resistant steels (≤2 mm) are produced in cold-reduced conditions. Docol W cold-reduced, corrosion resistant steels are available in two strength grades, with guaranteed yield strengths of 355 N/mm² and 700 N/mm².

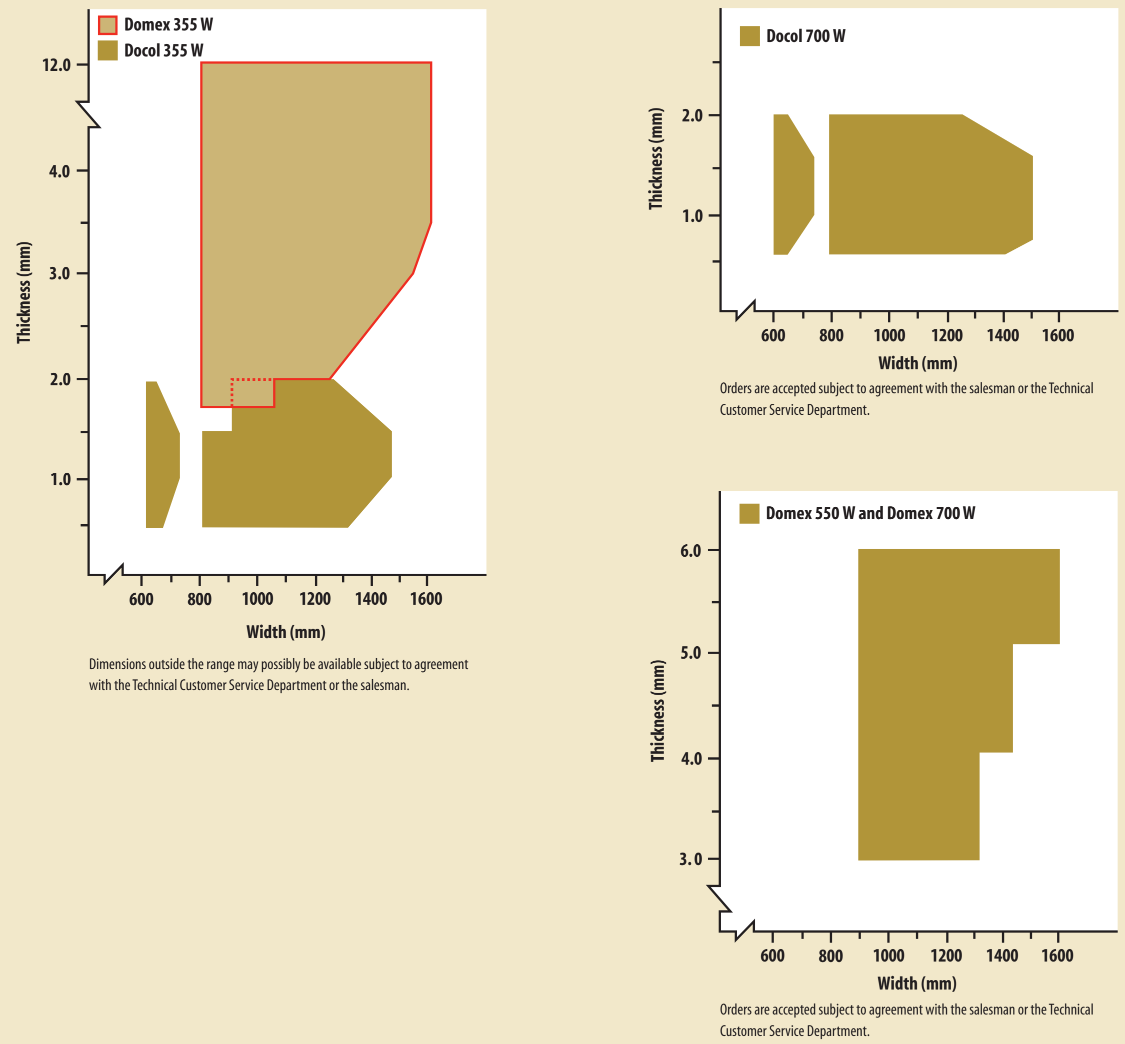
Heavier corrosion resistant steels (>2 mm) are produced in hot-rolled condition. Hot-rolled steels are available in three strength grades, with guaranteed minimum strengths of 355 N/mm², 550 N/mm² and 700 N/mm².

Cut-to-length dimensions

Steel grade	Thickness mm	Length mm
Docol 355 W	0.5-2	1000-8000
Domex 355 W	1.8-12	1500-13000
Domex 550 W	3-6	1500-13000
Docol 700 W *	0.5-2	1000-8000
Domex 700 W *	3-6	1500-13000

*) Grade in the course of development

Range of dimensions in coils



Physical properties					
Steel grade	EN 10155	Yield strength N/mm² min	Tensile strength N/mm² min	Elongation % min A_5	A_{80}
Docol 355 W	S355J0WP	355	450 *	–	22
Domex 355 W	S355J0WP	355	490 **	20	–
Domex 550 W	–	550	600	18	–
Docol 700 W ***	–	700	900	–	5
Domex 700 W ***	–	700	750	12	–

*) The tensile strength of cold-reduced material does not conform to EN 10155, **) For thicknesses < 3 mm, the min tensile strength is ≥ 510 N/mm², ***) Grade in the course of development.

Chemical composition (typical values)									
Steel grade	C (%)	Si (%)	Mn (%)	P (%)	S (%)	Cu (%)	Cr (%)	Al (%)	Micro-alloying elements
Docol 355 W	0.050	0.30	0.35	0.08	0.01	0.30	0.60	0.04	–
Domex 355 W	0.065	0.35	0.35	0.09	0.01	0.30	0.80	0.04	–
Domex 550 W	0.07	0.35	0.65	0.09	0.01	0.30	0.85	0.04	Added
Docol 700 W ***	0.13	0.50	1.20	0.01	0.004	0.40	0.50	0.04	Added
Domex 700 W ***	0.06	0.35	1.00	0.02	0.01	0.35	0.70	0.04	Added

***) Grade in the course of development.

Bending

Corrosion resistant steels combine high strength with good bendability. As in all bending of high strength steels, the bends should preferably be made across the direction of rolling. The punch radius is decisive to the inside diameter of the finished bend when bending corrosion resistant steels with a yield strength of ≥550 N/mm². On the other hand, when bending Docol/Domex 350 W, the die width is the most important parameter.

The adjacent table shows the minimum bending radius for corrosion resistant steels.

Bending		
Steel grade	Thickness mm	Min bending radius mm
Docol 355 W	0.5-2	0,5 x t
Domex 355 W	(2)-6	1,0 x t
	(6)-12	2,0 x t
Domex 550 W	3-6	1,0 x t
Docol 700 W ***	0.5-2	1,0 x t
Domex 700 W ***	3-6	2,0 x t

***) Grade in the course of development
t = sheet thickness

Hot strength

The properties that principally determine the usability of a steel at elevated temperature are the scaling temperature, hot strength and creep strength. These properties must therefore be taken into account when designing structures intended for elevated operating temperatures. The hot strength is determined by tensile testing at different temperatures.

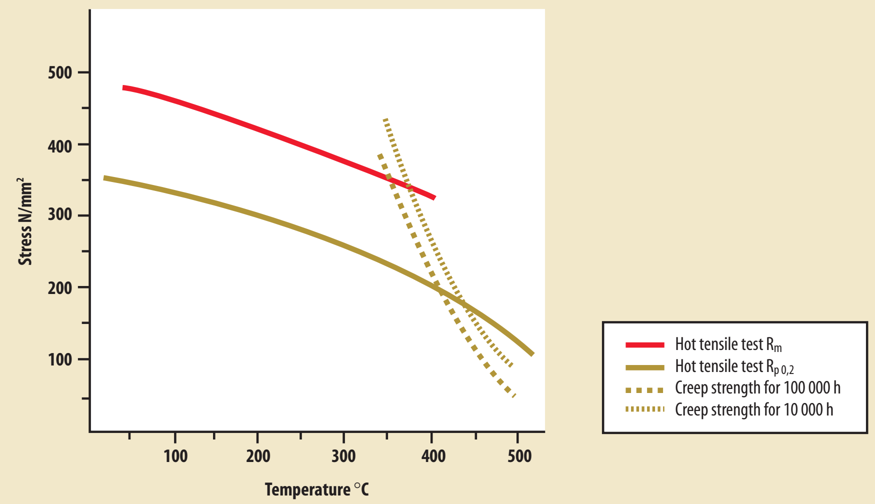
The creep strength is obtained by determining the load that the material can withstand without failure when exposed to a constant temperature for 10 000 or 100 000 hours.

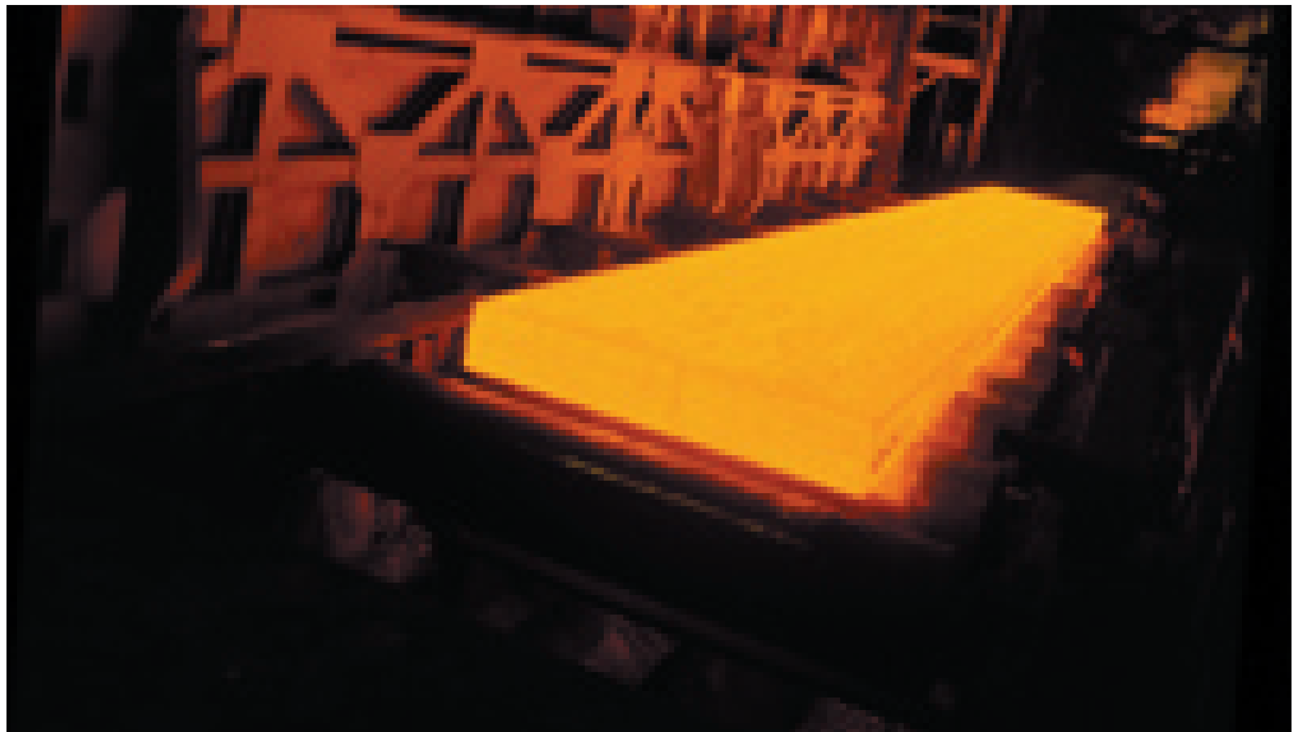
Values of hot strength and creep strength of corrosion resistant structural steels are plotted in the graph below. The hot strength is of interest within the temperature range below 400°C, whereas the creep strength is of interest in the range above 400°C.

Scaling temperature

By being alloyed with Cr and Cu, corrosion resistant structural steels have a scaling temperature of around 560°C, which is 35–40°C higher than that of plain carbon steel.

Static strength of Domex 355 W and Docol 355 W





Corrosion

Atmospheric corrosion

Porous, loosely adhering corrosion products are formed on the surface when plain carbon steels corrode. This layer of rust represents a very weak obstacle to continued corrosion attack.

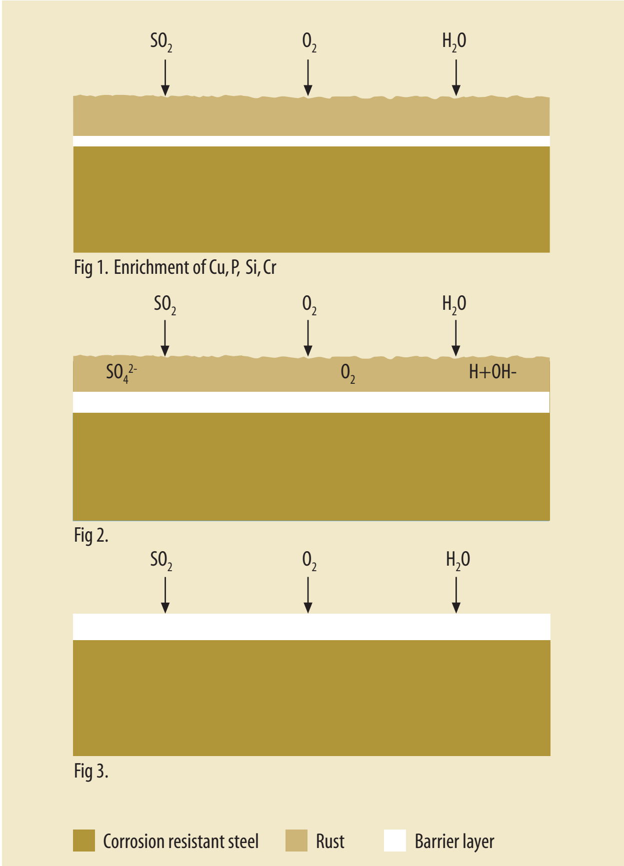
Under normal atmospheric conditions, corrosion resistant structural steels initially corrode in the same way as plain carbon steel (Fig. 1), although a more dense barrier of corrosion products will subsequently be formed, and the corrosion rate will decline with time (Fig. 2, 3).

The rate at which the barrier layer develops and the way in which it forms depends on a number of factors, principally the moisture and pollutant contents of the air, although the wind and sun conditions also play a certain role. The best protection against corrosion is obtained when the corrosion resistant steel is exposed freely and is subjected to varying dry and wet periods. In sulphurous environments, the protective layer will have formed after 1.5-2.5 years. On the other hand, in an aggressive marine environment, the formation of a dense protective barrier layer is more difficult, due to the presence of chloride ions and the long wet periods.

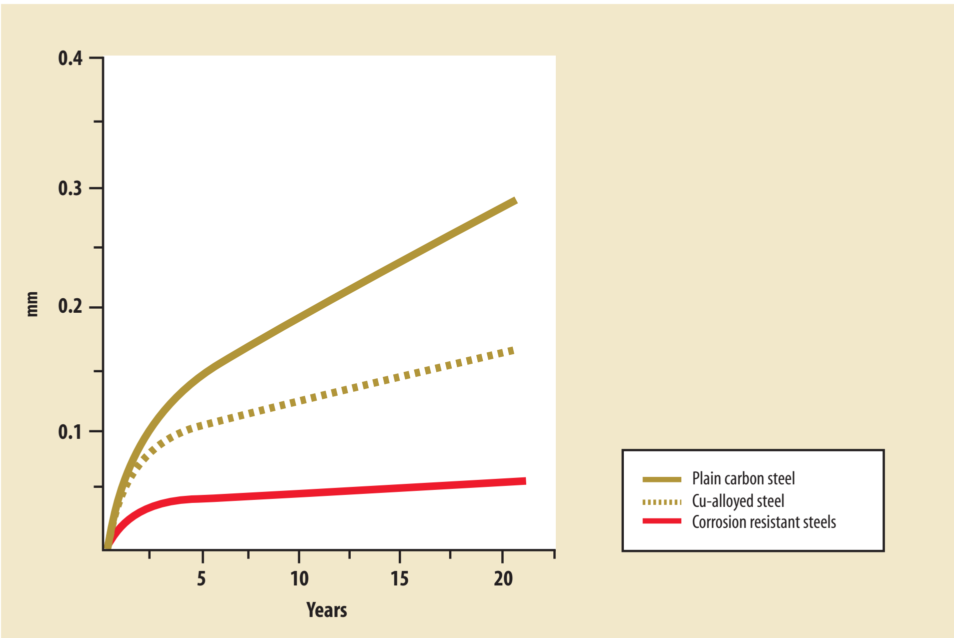
After only 10 years, the corrosion attack on corrosion resistant structural steels is less than half of that of plain carbon steels. and the difference then increases with time. Corrosion allowances in accordance with the table on the next page are recommended for the design of outdoor structures.

There are many published studies and also a standard (ASTM G-101-97) which show that corrosion resistant steels have better resistance to corrosion than ordinary plain carbon steels.

Tables 1 and 2 give some examples of material loss in different environments. Also note that corrosion resistant steels with a chemical composition conforming to ASTM A242 have better resistance to corrosion than those to ASTM A588. The chemical compositions of Domex W and Docol W give the steels a corrosion index calculated in accordance with the ASTM-G-101-97 standard corresponding to ASTM A 242 (Corten A).



The figures basically show how the barrier layer is formed.



Examples of the corrosion rate of a plain carbon steel, Cu-alloyed steel and corrosion resistant steels in a sulphurous environment.

Mean material loss
in μm after 16 years of exposure in urban and industrial environments

Material	Sweden	Great Britain	Germany	France
C steels	205	317	360	404
ASTM A242	138	198	208	221
ASTM A588	186	250	306	328

Table 1

Mean material loss
in μm after 16 years of exposure in marine environment

Material	Sweden	Great Britain	Germany	France
C steels	202	541	–	274
ASTM A242	116	249	–	165
ASTM A588	135	257	–	145

Table 2

Crevice corrosion

In corrosion resistant structural steels, the barrier layer is developed in the normal way in crevices in which moisture is allowed to dry out. Examples of such crevices are correctly designed bolted joints (see page 9). Due to the dense barrier layer formed, further corrosion in these crevices is inhibited.

Galvanic corrosion

Galvanic corrosion may occur if a corrosion resistant steel is in contact with other metals. However, practical experience has shown that on contact with stainless steel, no galvanic corrosion of any practical significance will occur on the corrosion resistant material. The barrier layer will develop in the normal way when the steel is exposed to the atmosphere. On contact with galvanized parts, the corrosion resistant steel will develop an area of lighter rust shade up to a few centimetres from the point of contact. This is due to the fact that the steel is protected cathodically by the zinc. On contact between corrosion resistant steel and other carbon steels, no increased corrosion will occur on either of the materials. Other material combinations than those mentioned here should be avoided, unless a corrosion specialist considers that the application is safe.

Corrosion in water and underground

Corrosion resistant structural steels used in water or underground offer no advantages compared to plain carbon steels. It is thus important for structures to be designed to avoid the accumulation of water and condensate pockets. If corrosion resistant structural steels are used underground, the material should be coated with anti-corrosion paint.

Corrosion by flue gases

After many years of service in central heating boilers, industrial chimneys and chimney flue pipes, corrosion resistant structural steels have given convincing proof that the material is suitable for service in flue gases. Studies of various types have been undertaken and have shown that corrosion resistant structural steels are more resistant than other materials.

The studies are representative principally for the temperature range of 100-120°C in which SO_3 condenses and may cause serious corrosion.

At temperatures below around 70°C when the gas conditions may drop below the dew point and dilute sulphuric acid is formed on the walls, corrosion may be even more serious.

It is important to avoid such low temperatures. This can be done by adjusting the cross-sectional area of the flue gas passage and/or insulating the flue pipe. Particularly careful attention should be given to the corrosion conditions in the flue gas passages from heating plants at temperatures just over 100°C.

Corrosion allowance as per BSK 99, one-sided general material loss[1], mm/10 years

Corrosivity category	Corrosivity of the environment	Structural steels: First 10 years	Structural steels: Subsequently	Corrosion resistant steels: First 10 years	Corrosion resistant steels: Subsequently
C2	Low	0.05	0.015	0.02	0.01
C3	Moderate	0.12	0.06	0.08	0.05
C4	High	0.30	0.20	0.15	0.10

[1] The values for material loss are obtained from ISO 5224. The table gives the upper limit of each interval.

Welding

Domex 355 W, Domex 550 W, Domex 700 W, Docol 355 W and Docol 700 W high strength corrosion resistant steels have gained their improved anti-corrosion properties by small additions of copper, chromium, phosphorus and silicon alloying elements. These additives cause no problems when steels of this type are welded. This is due to the very low contents of other elements (such as carbon and manganese) in the steels.

Electrodes that have been specifically developed for this steel type are recommended for welding. These electrodes have elevated contents of nickel and copper to ensure that the weld metal will also have a composition that ensures good anti-corrosion properties.

Matching electrodes for these steels are usually filler metals with corrosion properties corresponding to those of Domex W and Docol W steels. These filler metals are supplied in strength grades R_e of around 500 N/mm^2. From the strength aspect, the filler metals is over-matched for Domex 355 W and Docol 355 W, and slightly under-matched for Domex 550 W. Compared to Domex 700 W and Docol 700 W with minimum yield strengths of 700 N/mm^2, these filler metals are clearly under-matched. However, the alloying elements in the parent material will be mixed in during welding, and the strength of the welded joint will therefore be just below or about the same as the minimum requirement for the parent material, particularly if the bead is retained and multi-pass welding is employed. For thicknesses in excess 4 mm, two runs are recommended for Domex 700 W. If a matching filler metal is required from the strength aspect, filler metals that are intended for ordinary structural steels are available. However, it should be borne in mind that the resistance to corrosion at the welded joint will be somewhat lower.

Examples of suitable filler metals for welding corrosion resistant steels

Manual metal arc welding MMA	Gas shielded metal arc welding MAG		Submerged arc welding SAW	Manufacturer
	Cored electrod	Solid wire	Wire/powder	
OK 73.08, OK 50.10	OK Tubrod 14.01	OK Autrod 13.26	OK Autrod 13.36 Flux 10.81 ; 10.71	ESAB
Filarc 35Z, Filarc 85CP		Filarc PZ 6112		ESAB
Tencord Kb	Fluxofil 18	Spoolcord TD-COR	Fluxocord 48/OP 121TT ; OP 41 TT	Oerlikon
			L61/Flux Axxxx10	Lincoln

Bolted joints

Bolted joints should be designed to suit their required performance, and efforts should be made to achieve direct force transfer and a compact design. The fasteners should be located so that adequate space will be available for satisfactory tightening.

To prevent bursting by rust, the maximum distance from the edge and the maximum distance between centres should be in accordance with the adjacent table.

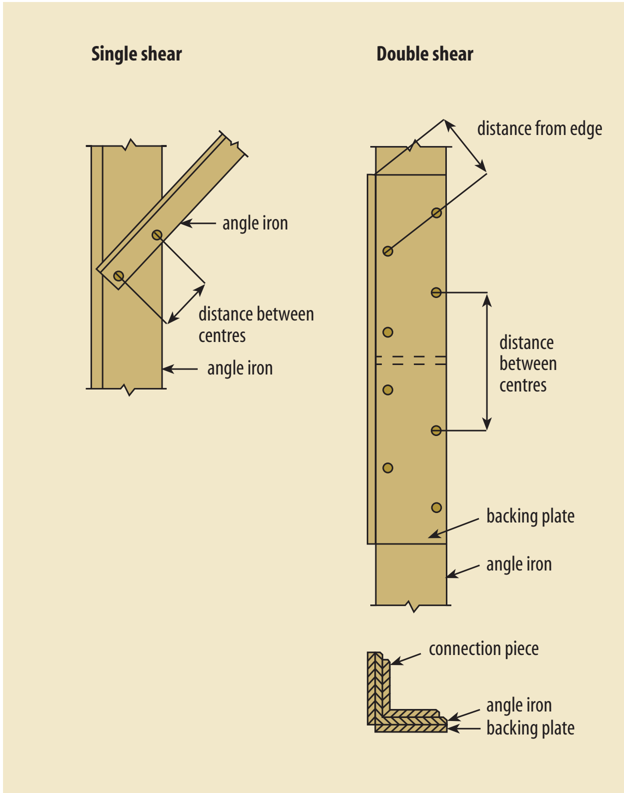
In dynamically loaded joints in which the contact surfaces continually rub against one another, the barrier layer will be unable to form. Gaskets or painting between the contact surfaces are recommended for such joints.

Avoid contact between unprotected corrosion resistant steel and other metals in order to prevent the formation of a galvanic element. Bear this in mind when using bolts, nuts, rivets and washers in joints.

Locations of bolts

Maximum distance from the edge		Maximum distance between centres
unstiffened edges	stiffened edges	
≤ 3d or 6 t [1)]	≤ 4d or 8 t [1)]	≤ 7d or 14 t [1)]

1) Whichever is the smallest, d = bolt diameter, t = material thickness



Painting – if required

The resistance of a well-developed oxide layer and its appearance make painting superfluous. The "painting" given to the steel by nature is more durable than any form of conventional painting. Bridges, tanks, power line masts and crash barriers are some typical examples of structures that normally require extensive painting. The total cost of new painting and maintenance can then be very high. It is realistic to assume that repainting, including cleaning, amounts to 15–20% of the cost of the steel structure. In addition, there is the cost of maintenance painting that will be necessary from time to time. If a special colour is required, such as for a bridge structure of Domex 355 W, only the outsides of the beams need be painted.

Major savings can also be made from the maintenance aspect by using corrosion resistant steels, even if a different colour of the structure is required. The "self-healing" feature of the material increases the useful life of the paint by 100–200% compared to the painting of ordinary plain carbon steel. "Self healing" means that creepage of rust under the paint (causing the paint to peel off) that quickly occurs on a plain carbon steel when the paint coat is damaged is greatly reduced on corrosion resistant steels. This is due to the fact that the latter do not form porous, swelling rust when they corrode.

Corrosion resistant steels can be pre-treated and painted with the same paint system as ordinary plain carbon steels. The table to the right gives an example of the surface roughness after the normal blast cleaning used in the surface treatment of containers. The values show that the roughness of the surface provides good adhesion of the paint system to the steel surface.

Painting of corrosion resistant steels can provide benefits in applications in which the surface is subjected to frequent blows and shocks and sustains serious damage, while the environment is alternately humid and dry. A protective oxide layer will then be formed on the damaged surfaces, and corrosion will be arrested.

Surface roughness R_z
after normal pre-treatment by blast cleaning

Material	R_z, µm
Docol 700 W	$22 < R_z < 48$
Domex 550 W	$34 < R_z < 53$
Domex 355 W	$37 < R_z < 62$

General advice

If a structure made of corrosion resistant structural steels is to be perfectly satisfactory, the following should be borne in mind:

- The surface structure of corrosion resistant steels varies with the dimensions. The surface of thin material is relatively smooth. Thicker steel has a coarser and rougher surface structure.
- The design should be such that it does not collect water or attract moisture over long periods of time. Check that crevices and overlaps are securely sealed.
- Ensure satisfactory water run-off from structures made of a corrosion resistant structural steel. Discoloration may otherwise occur on adjacent structural elements or foundations. In adjacent parts, use materials that are resistant to fouling and from which iron oxides can easily be removed.

Examples of such materials are:

- gloss enamel
- anodized and untreated aluminium
- stainless steel
- neoprene and similar smooth plastic materials
- all types of gloss paints
- glazed roofing tiles and bricks
- bright and tight silicon and quartz plates
- dark-coloured concrete

Avoid contact between unprotected corrosion resistant steel and other metals, so that no galvanic elements will occur. Bear this in mind when making joints using bolts, nuts, rivets and washers. All connecting elements should be of corrosion resistant structural steel. See also page 7 – Galvanic corrosion.

SSAB Tunnplåt AB is the largest Scandinavian sheet steel manufacturer and a leader in Europe in the development of high strength, extra-high strength and ultra-high strength steels.

SSAB Tunnplåt is a member of the SSAB Swedish Steel Group, has a turnover of SEK 9 billion, and has around 4000 employees in Sweden. The company produces about 2.7 million tonnes of sheet steel annually.

Our environmental policy involves continual improvements to the efficiency of production processes and environmental care plants, and development of the environmental properties of our products from the life cycle perspective.

We produce the following steels in our modern, high-efficiency production lines and rolling mills for strip products:

DOMEX
hot-rolled steel sheet

DOCOL
cold-reduced steel sheet

DOGAL
metal-coated steel sheet

ALUZINK
aluminium-zinc coated steel sheet

PRELAQ
prepainted steel sheet

We assist our customers in selecting the steels that are best suited for improving their competitiveness. Our strength lies in the quality of our products, our reliability of supply, and our flexible technical customer service.

ssabtunnplat.com

SSAB Tunnplåt AB
SE-781 84 Borlänge
Sweden
Tel +46 243 700 00
Fax +46 243 720 00
office@ssabtunnplat.com
www.ssabtunnplat.com

France
SSAB Swedish Steel SA
Phone +33-1-55 61 91 00
Fax +33-1-55 61 91 09

Germany
SSAB Swedish Steel GmbH
Phone +49 211 9125-0
Fax +49 211 9125-129

SSAB Swedish Steel GmbH
Phone +49 711 68784-0
Fax +49 711 68784-13

SSAB Swedish Steel GmbH
Phone +49 2304 9520-04
Fax +49 2304 9520-06

SSAB Swedish Steel GmbH
Phone +49 851 49087-40
Fax +49 851 49087-41

Great Britain
SSAB Swedish Steel Ltd.
Phone +44-1905-795794
Fax +44-1905-794736

Italy
SSAB Swedish Steel S.p.A
Phone +39-030-905 881 1
Fax +39-030-905 893 0

The Netherlands
SSAB Swedish Steel BV
Phone +31 24 679 05 50
Fax +31 24 679 05 55

Poland
SSAB Swedish Steel Sp zo.o
Phone +48-602725985
Fax +48 22 7725171

Portugal
SSAB Swedish Steel Portugal
Phone +351 256 371 610
Fax +351 256 371 619

Spain
SSAB Swedish Steel S.L.
Phone +34 91 3005422
Fax +34 91 3889697

USA
SSAB Swedish Steel Inc.
Phone +1-412-269 21 20
Fax +1-412-269 21 24

South Africa
SSAB Swedish Steel (Pty) Ltd
Phone +27 11 824 3917 / 8 / 9
+27 11 827 0311
Fax +27 11 824 2169

China
SSAB Swedish Steel
Phone +86 10 6466 3441
Fax +86 10 6466 3442

Japan
SSAB Swedish Steel Ltd
Phone +81-3-3456-3447
Fax +81-3-3456-3449

Korea
SSAB Tunnplåt Korea Branch
Phone +82-31-906-2770
Fax +82-31-906-2773

SSAB TUNNPLÅT

GB 394 www.heimer-co.se