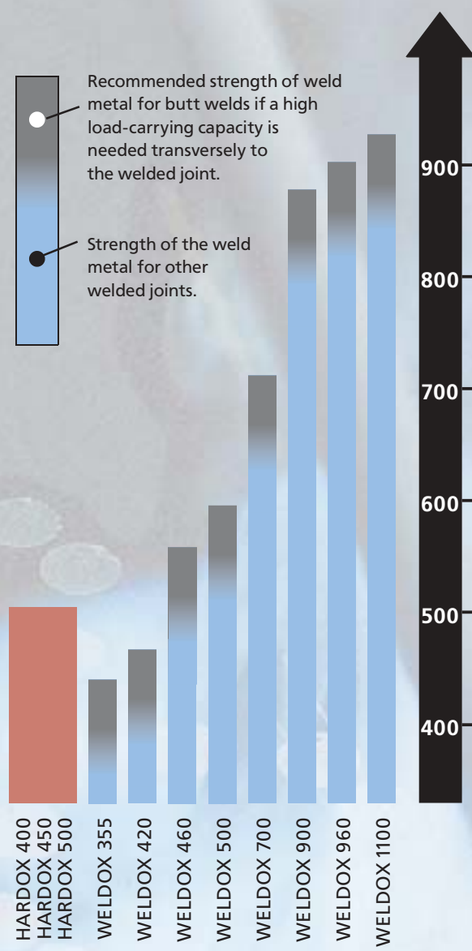

Filler material (AWS-classes)

MMA Manual metal arc		SAW Submerged arc		MIG / MAG Gas metal arc		FCAW Flux cored arc	
AWS A5.5	E 12018	AWS A5.23	F 12AX-EX	AWS A5.28	ER 120S-X	AWS A5.29	E 12XT-X
		AWS A5.23	F 11AX-EX	AWS A5.28	ER 110S-X	AWS A5.29	E 11XT-X
AWS A5.5	E 11018						
AWS A5.5	E 10018	AWS A5.23	F 10AX-EX	AWS A5.28	ER 100S-X	AWS A5.29	E 10XT-X
AWS A5.5	E 9018						
		AWS A5.23	F 9AX-EX	AWS A5.28	ER 90S-X	AWS A5.29	E 9XT-X
AWS A5.5	E 8018	AWS A5.23	F 8AX-EX	AWS A5.28	ER 80S-X	AWS A5.29	E 8XT-X
AWS A5.5	E 8016	AWS A5.23	F 7AX-EX				
AWS A5.5	E 7028						
AWS A5.1	E 7018	AWS A5.17	F 7AX-EX	AWS A5.18	ER 70S-X	AWS A5.20	E 7XT-X
AWS A5.1	E 7016						

Note : "X" stands for one or more characters.

▲ General recommendations for the selection of filler materials for welding HARDOX and WELDOX steels

- Basic flux should always be employed in FCAW, SAW and MMA welding.
- The impact toughness of the weld metal should be at least the same as that of the plate.
- Always use a filler material with low hydrogen content (HD ≤ 5 ml / 100 g).

For more detailed information, please refer to the *Handbook on Welding of Oxelösund steels* which can be obtained from us free of charge.

You can also order the following metalworking brochures: "*Bending, shearing*" and "*Machining*". and "*Cutting*".

You are also welcome to get in touch with one of our application engineers who will be pleased to provide advice and recommendations concerning welding, selection of materials, machining and other working, and surface treatment.

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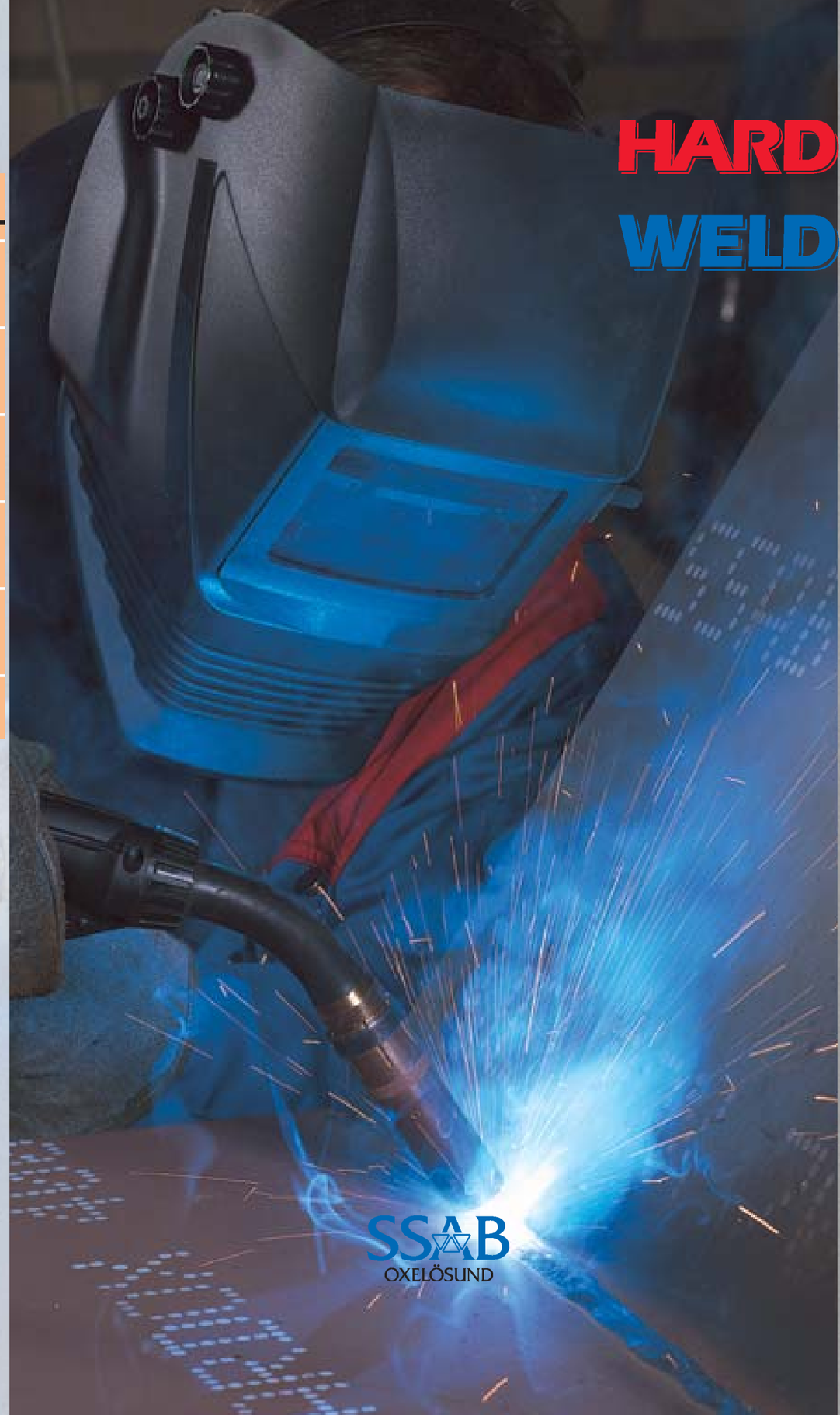
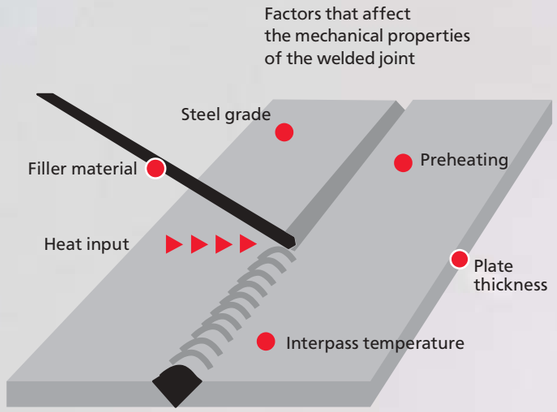


SSAB Oxelösund steel grades in HARDOX wear plate and WELDOX high strength structural plate have low contents of alloying elements and thus have low carbon equivalents. As a result, they can be easily welded to all ordinary structural plate using any conventional arc welding methods.



When HARDOX plate is welded, the objectives are:

- To maintain the hardness in the heat affected zone (HAZ).
- To achieve good toughness of the HAZ.

When WELDOX plate is welded, the objectives are:

- To obtain proper strength in the welded joint.
- To achieve good toughness of the welded joint.

HARDOX and WELDOX have low carbon equivalents for their strength class

A steel with a *low* carbon equivalent (CEV) has *better* weldability than a steel with a high value. Typical CEV values for a particular plate thickness are given in our data sheets.

The carbon equivalent (according to the IIW) can be calculated from the following equation:

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

Steel grade	Thickness range	Carbon equivalent CEV (IIW)*
S 355	5–100 mm	0.39–0.43
WELDOX 355	8–25 mm	0.34–0.37
WELDOX 420	6–80 mm	0.37–0.39
WELDOX 460	6–80 mm	0.37–0.42
WELDOX 500	8–80 mm	0.37–0.42
WELDOX 700	4–130 mm	0.39–0.64
WELDOX 900	4–80 mm	0.56
WELDOX 960	4–50 mm	0.56–0.64
WELDOX 1100	5–40 mm	0.68–0.72
HARDOX 400	4–130 mm	0.36–0.70
HARDOX 450	4–80 mm	0.41–0.62
HARDOX 500	5–80 mm	0.58–0.68

*) Typical values

Workpiece temperature during welding

Whenever structural and wear-resistant steels are welded, it is important to minimize the risk of cold cracking (also known as hydrogen cracking or delayed cracking). The occurrence of hydrogen with the presence of stresses in the welded joint is the main reason for such cracking.

The risk of cracking can be minimized by:

- preheating the parent material before welding.
- ensuring that the joint surfaces are perfectly clean and dry.
- minimizing the shrinkage stresses. This can be achieved by a good fit between the workpieces and a well planned sequence of weld runs (balanced welding).
- selecting a filler material with low hydrogen content.

Preheating

Preheating is most important in tack welding and in welding of the root pass.

The higher the temperature during and after welding, the easier it will be for the hydrogen to escape from the steel.

The need for preheating increases with the plate thickness (see the table on the next page) in order to compensate for the faster cooling of thick plate, and because thick plate has a higher CEV value than thinner plate.

If the ambient humidity is high and/or the temperature is below +5°C, the tabulated value should be increased by 25°C. Correspondingly, the temperature should be increased if the workpiece being welded is rigidly restrained.

If different steel grades are welded together or if the electrodes used for welding have a higher CEV than the parent material, the necessary preheating is determined by the steel (or electrode) with the highest carbon equivalent.

Post-heating

Post-heating of the welded joint immediately after welding also makes it easier for hydrogen to escape from the steel.

The post-heating temperature should be the same as the preheating temperature.

The soaking time should be at least 5 minutes per mm of plate thickness, although not less than one hour.

Recommended preheating temperatures

The recommended workpiece temperatures are based on the assumption that:

– the hydrogen content does not exceed 5 ml/100 g of weld metal

– the heat input is approximately 1,7 kJ/mm

*) The filler material determines the preheating temperature if its carbon equivalent is higher than that of the plate.

…for different combined plate thicknesses [mm]

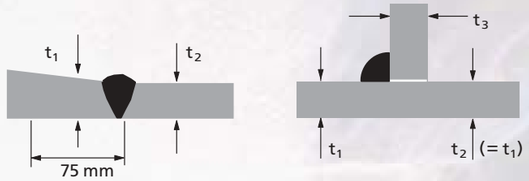
$t_1+t_2+t_3$ =	10	20	30	40	50	60	70	80	90	100	110	120	130
S 355 (SS 2132)											75°C		
WELDOX 355													
WELDOX 420/460				Room temperature							75°C		
WELDOX 500											75°C		
WELDOX 700						75°C				100°C		150°C	
WELDOX 900 *		75					100°C					150°C	
WELDOX 960 *		75					100°C					150°C	
WELDOX 1100 *		100		125°C			150°C				175°C		
HARDOX 400					75°C			100°C			175°C		
HARDOX 450					100°C			125°C			175°C		
HARDOX 500		100	125	150°C				175°C					

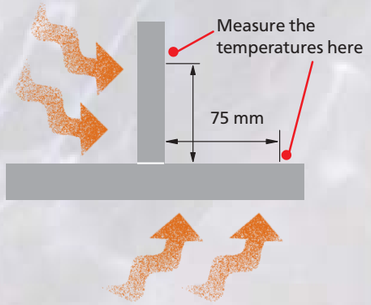
Recommended interpass temp.

Steel grade	Interpass temp.
S 355 (SS 2132)	225–250°C
WELDOX 355	225–250°C
WELDOX 420/460	225–250°C
WELDOX 500	200–225°C
WELDOX 700	200–225°C
WELDOX 900	150–175°C
WELDOX 960	150–175°C
WELDOX 1100	150–175°C
HARDOX 400	150–175°C
HARDOX 450	150–175°C
HARDOX 500	150–175°C

Combined plate thickness, mm

t_1 = mean thickness within a distance of 75 mm from the weld metal.





Post-treatment

Post weld heat treatment (PWHT)

PWHT is carried out to reduce the residual stresses after welding.

WELDOX should be post weld heat treated only if this is specified in the design rules.

HARDOX and WELDOX 1100 must not be subjected to PWHT.

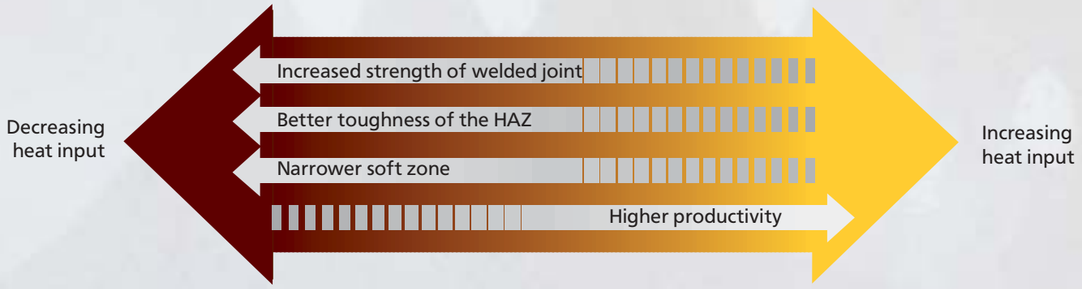
Measures to increase the fatigue strength

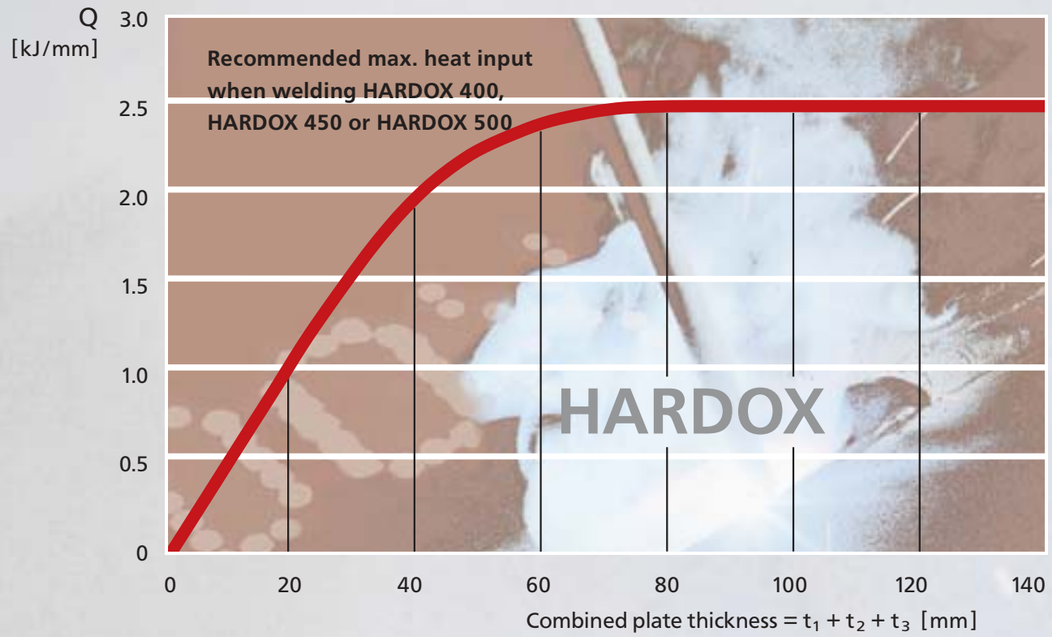
The fatigue strength of a welded joint can be increased by various types of post-treatment. Such treatments lower the stress concentrations and thus give a smoother transition between the weld and plate.

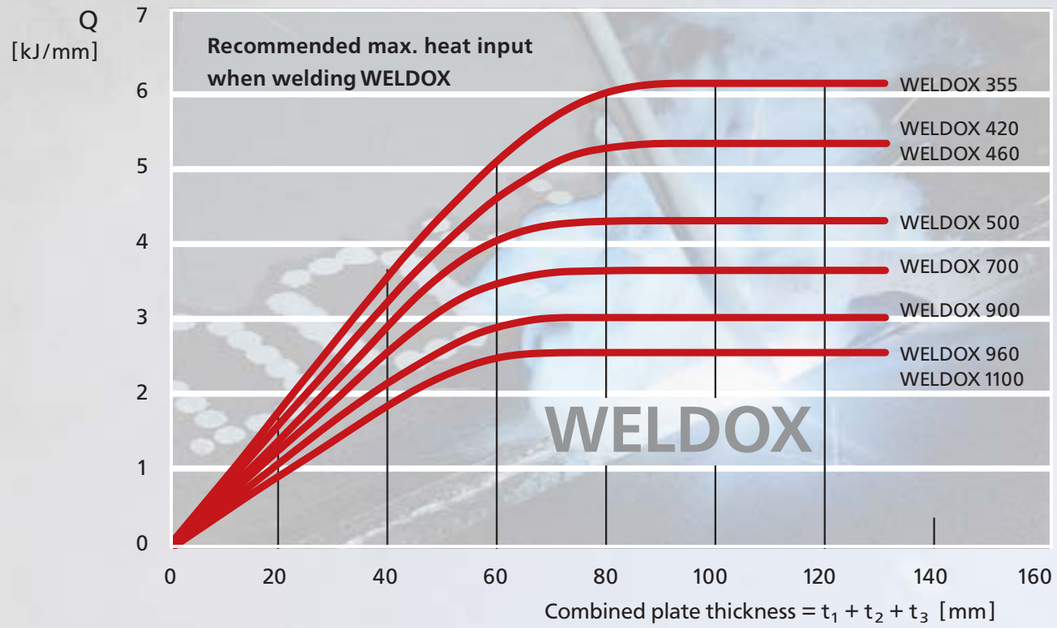
For further information, please consult the *Handbook on Welding of Oxelösund steels*.

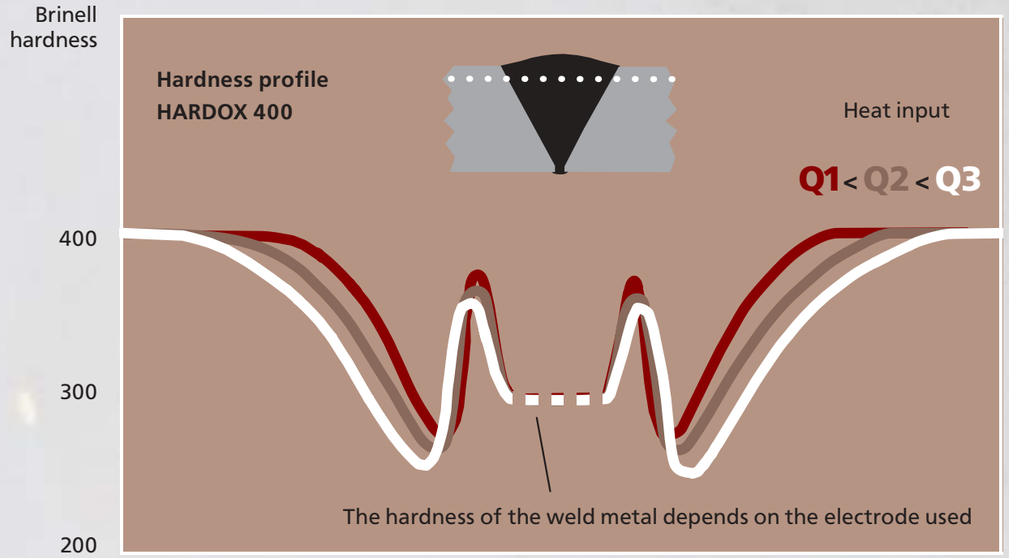
Selection of heat input

The following heat input limitations are recommended for welded joints in HARDOX or WELDOX. A heat input below this level produces a satisfactory combination of toughness, strength and preserved hardness of the heat affected zone (HAZ).









To calculate the heat input

$$Q = \frac{\eta \cdot U \cdot I \cdot 60}{v \cdot 1000}$$

Q = Heat input [kJ/mm]
U = Voltage [V]
I = Current [A]
v = Welding speed [mm/min]
η = Arc efficiency factor

Arc efficiency factor η

Welding method	Arc efficiency factor η
Manual metal arc (MMA)	0.8
Gas metal arc (MIG/MAG)	0.8–0.9
Flux cored arc (FCAW)	0.9
Submerged arc (SAW)	1.0
TIG (GTAW)	0.7

Selection of filler material *

All conventional arc welding methods intended for welding ordinary and high strength plate can be used for welding HARDOX and WELDOX.

The choice of filler material is determined by the demands made on the mechanical properties of the welded joint in each individual case.

Basic electrodes should be used for welding HARDOX and WELDOX. Choose a filler material which gives a hydrogen content of ≤ 5 ml / 100 g in the weld metal.

The following alternatives are available when selecting the yield strength of the filler material :

1) Undermatching weld metal (the weld metal has a **lower** yield strength** than the parent material).

2) Matching weld metal (the weld metal and parent material have **the same** yield strength**.

3) Overmatching weld metal (the weld metal has a **higher** yield strength** than the parent material).

When steel grades in the range from WELDOX 700 to WELDOX 1100 are welded, it is advisable to combine electrodes with different degrees of matching, e.g. soft electrodes in the root run and electrodes of higher strength in the filler beads.

*) *See the reverse side of the brochure for a list of AWS classes for filler material.*

**) *This refers to the nominal minimum value of the yield strength.*

The major benefits of selecting low-strength filler material rather than high-strength filler material (yield strength in excess of 500 N/mm^2) are :

- higher toughness of the weld metal,
- improved ductility of the welded joint,
- reduced sensitivity to cracking.

For fillet welds, it is always advisable to select undermatching filler material.

Use soft electrodes for welding HARDOX

HARDOX should be welded with soft basic electrodes. A soft electrode is a filler material with a yield strength below 500 N/mm^2. Such electrodes reduce the residual stress level in the joint and thus its sensitivity to cold cracking.

If the weld is located so that it is subjected to heavy wear, hard facing electrodes can be used for the cap beads.

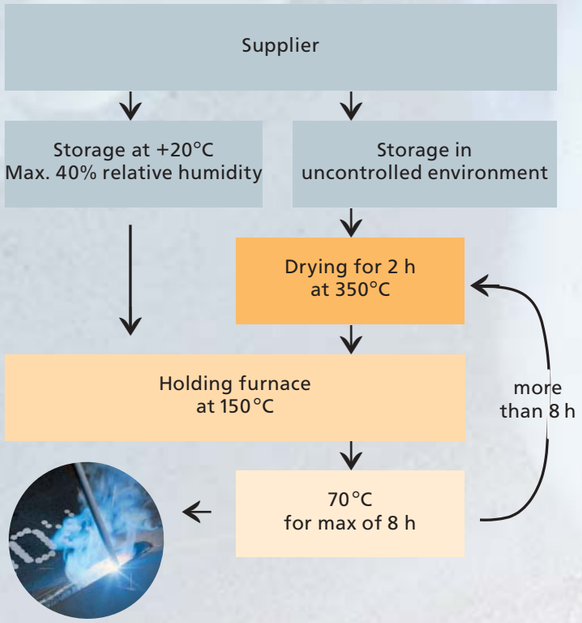
HARDOX can very successfully be welded with austenitic stainless steel filler material in the following cases :

- if the workpiece is rigidly restrained
- if the workpiece cannot be preheated
- if the plate is thicker than 60 mm

Recommended degree of matching when HARDOX and WELDOX steels are welded

WELDOX 355 / 420	Overmatching
WELDOX 460 / 500	Overmatching / Matching
WELDOX 700	Matching / Undermatching
WELDOX 900 / 960	Undermatching
WELDOX 1100	Undermatching
HARDOX 400 / 450 / 500	Undermatching

In order to prevent moisture absorption, the filler material should be stored in accordance with the manufacturer's recommendations. If there is risk of moisture having been absorbed, the filler material must be scrapped or re-dried in accordance with the manufacturer's instructions.



Welding of primer coated plate

Welding of plate coated with anti-corrosion primer may give rise to varying amounts of porosity. However, porosity can be minimized by selecting the right type and coat thickness of primer and by employing suitable welding parameters. Welding can then be carried out within the limits specified by the relevant standards, without the need for removing the primer.

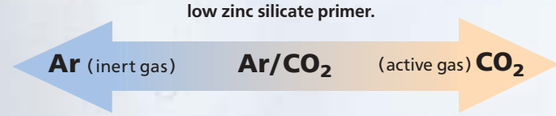
Before delivery, stock HARDOX and WELDOX plate are protected against corrosion by a low zinc silicate primer. This paint has been specially developed to minimize the pore volumes during welding. As a result, welding may be carried out directly onto the primer coat, which contributes towards improved productivity in the workshop.

If the plate is anti-corrosion coated with PVB (polyvinyl butyral) or an epoxy primer, the paint should be removed before welding in order to ensure satisfactory weld quality.

Work hygiene

When welding or grinding plate coated with primer, make sure that the work area is well ventilated.

Effect of the shielding gas on the porosity of the weld metal in FCAW, MIG / MAG welding of plate painted with low zinc silicate primer.

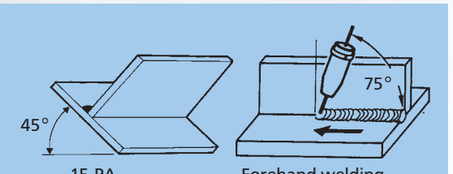


High porosity of the weld metal. Stable arc.

Low porosity. Weld spatter/clogging of welding nozzle.

Recommendations for ensuring good weld quality when welding HARDOX and WELDOX painted with low zinc silicate primer.

Welding method	Flux cored arc (FCAW)	MAG	MMA
Flux	Basic	–	Basic
Shielding gas	75% Ar / 25% CO_2	75% Ar / 25% CO_2	–
Electrode angle	75°	75°	60–90°
Welding position	1F, PA	1F, PA	1F, PA
Welding direction	Forehand	Forehand	Backhand



1F, PA — Forehand welding

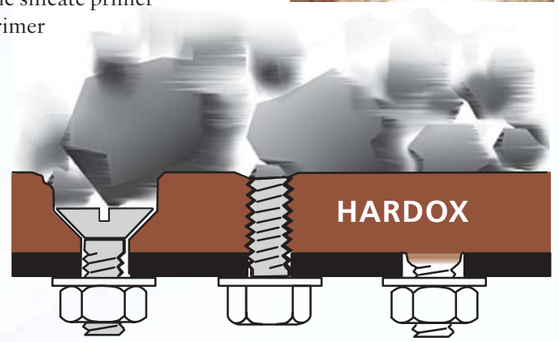
Stud welding

HARDOX and WELDOX are very well suited for stud welding and need not be preheated for welding at room temperature.

Stud welding can be carried out directly on the following surfaces, provided that they are dry and thoroughly cleaned :

- bright
- painted with low zinc silicate primer
- painted with PVB primer

Stud welding is a fast, simple and economical method of securing bolts, screws, studs, etc. to a metal surface. The method can often replace costly machining operations such as drilling, countersinking and tapping. The procedure is simpler than traditional welding and can be carried out even by personnel who are not trained welders.



Stud welding provides a more protected installation than the use of countersunk head screws or bolts screwed into tapped holes.

This reduces the necessary wear allowance and increases the useful life.