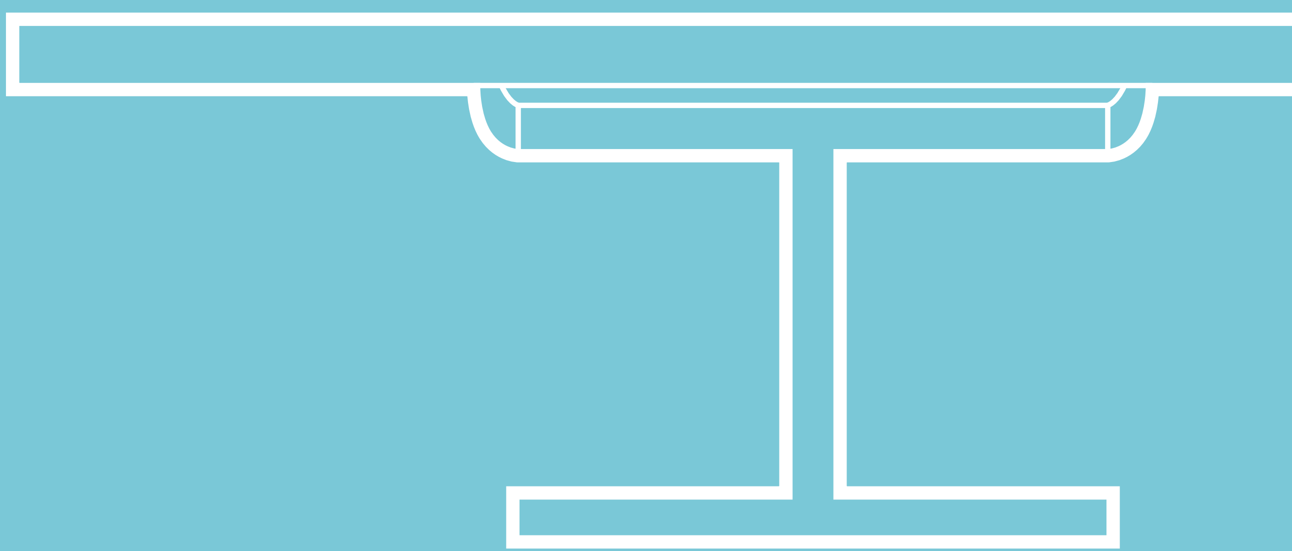
Corus Construction & Industrial

Steel plates for offshore structural applications

A guide to fabrication of primary structural steel plate



This brochure is a guide to the fabrication of steel plates produced by Corus for offshore structural applications.

In addition to welding, the processes covered include shearing, flame cutting, plasma cutting, cold forming, warm & hot forming, machining, drilling and boring. Corus have a wealth of expertise in this area gained whilst working closely with designers and fabricators over a number of years. We will be pleased to offer guidance and advice for any specific fabrication application.

In the following text, the steel types are referred to by the delivery condition of the plate, i.e. normalised, thermomechanically controlled rolled (TMCR) or roller quenched and tempered (RQT). The table below is a guide to which grades are available for each heat treatment condition. For full clarification please refer to the plate test certificate.

Delivery condition	Grade
Normalised	BS 7191 355EM / EMZ EN 10225 S355G7+N EN 10225 S355G8+N EN 10225 S355G9+N EN 10225 S355G10+N API 2H grade 50
TMCR	BS 7191 355EM / EMZ EN 10225 S355G7+M EN 10225 S355G8+M EN 10225 S355G9+M EN 10225 S355G10+M API 2W grade 50 / 50T
RQT	BS 7191 450EM / EMZ EN 10225 S420G1+Q EN 10225 S420G2+Q EN 10225 S460G1+Q EN 10225 S460G2+Q API 2Y grade 60

Shearing

RQT high strength steel plates can be cold sheared. In view of the high strength level relative to mild steel and other structural steels, proportionately higher shearing power is required for any given thickness.

Flame cutting

Plates may be cut satisfactorily with standard oxy-gas equipment. Neither preheating nor postheating is normally required. However, where fabrication codes specify maximum hardness levels, attention must be paid to the selection of appropriate gas cutting procedures.

Care should be taken to ensure that flame cut edges are free from sharp notches, as these may prove detrimental to subsequent cold forming operations. Prior to cold forming, gas cut edges should be ground back in regions to be bent.

In multiple cutting situations, care is required to achieve a balanced arrangement of the cutting torches to minimise plate distortion.

Many fabrication standards stipulate that cut edges not fully incorporated into a weld should be ground back to remove the hard edge. It is recommended that these standards are followed.

Plasma cutting

Plates may be plasma cut within the operating thickness ranges of the equipment. All plasma cut edges which form part of a weld preparation should be incorporated fully into the weld. As with flame cut edges, plasma cut edges should be ground back in the regions to be bent prior to cold forming.

Cold forming

All types of structural steel plate described in this brochure can be readily cold formed. Due to the higher strength level of RQT steels, the power required for cold forming is proportionately greater than that required for mild steel plates of the same thickness. For the same reason, greater springback will be experienced for which due allowance must be made.

Bending and brake press forming of RQT steels should, where possible, be carried out with the axis of bending at right angles to the rolling direction. Minimum values of bending radius and of die opening for 90° bends, expressed as multiples of the plate thickness (t), are given in the following table.

Bend axis vs. rolling direction	Minimum inside bending radius	Minimum die opening
Perpendicular	3.0t	8.5t
Parallel	4.0t	10.0t

Customers with bending requirements more stringent than these are asked to state the requirement at the time of ordering.

Warm and hot forming

Normalised steel grades are suitable for both warm forming and hot forming.

Thermomechanically controlled rolled (TMCR) grades are not suitable for hot forming as raising the temperature above 650°C will result in an irretrievable deterioration of properties. Warm forming of TMCR plates should therefore be carried out in carefully controlled conditions, with particular emphasis on control of the upper limit of temperature.

Roller quenched & tempered (RQT) high strength steels are not suitable for hot forming. Should it be necessary to consider a warm forming operation or a line heating operation, it should be performed at a temperature below 550°C and at least 50°C below the tempering temperature stated on the inspection certificate. Total heating times for single or multiple forming operations should be restricted to less than 1 hour per 25mm of plate thickness.

As RQT high strength steels derive their properties from efficient quenching, re-quenching and tempering after hot forming operations is not recommended.

Machining, drilling and boring

All Corus steels can be machined, drilled and bored. It should be noted that, due to the low sulphur levels of these steels, power requirements are likely to be greater than with high sulphur steels and tool life may be affected. Normal tool life will be maintained by a reduction of about 30% in cutting speed relative to values given in tool manufacturers' tables of machining and drilling parameters for steels at the equivalent strength level.

Welding

The steel plates described in this brochure are readily weldable and the guidance given here is intended to form the basis for the development of welding methodology outlined in BS EN1011-2:2001 which has replaced BS5135.

Corus will discuss and advise on specific applications or developments which may involve weld procedures outwith the indicated ranges.

There may be cost and productivity implications in the selection of a particular weld procedure. Corus will be happy to discuss and offer guidance. Contact details are on the back cover.

Consumables

There are a wide range of consumables suitable for welding steels for offshore applications. The choice of consumables may be dependent on factors other than matching mechanical properties. Low hydrogen practices should be employed for fabrication of offshore structures.

Guidance in the use of consumables and on the achievement of specific mechanical properties in the heat affected zone (HAZ) can be provided by Corus.

Weld procedures

The selection of weld procedures for the fabrication of offshore structures must take into account a number of factors linked to the properties of the steel plates to be welded. Cracking of the weld heat affected zone (HAZ) must be avoided with HAZ hardness kept below critical levels. HAZ toughness, which may be expressed either as Charpy-V impact energy or as Crack Tip Opening

Displacement (CTOD) must be kept above critical values to eliminate the risk of brittle failure in service. Methods of evaluating the effects of the weld thermal cycle on these properties have evolved from years of practical experience coupled with extensive laboratory research, and are included in welding standards such as British Standard BS7363:1990 (Controlled Thermal Severity Testing) and BS EN1011-2: 2001. Guidance on the selection of welding procedures using the methodology contained in BS EN1011-2:2001 is available on request from Corus.

The recommended upper limit of heat input are shown below:

Delivery condition	Maximum recommended heat input
Normalised	3.5 kJ/mm
TMCR	5.0 kJ/mm
RQT	3.5 kJ/mm

There may be occasions when productivity considerations could require the use of higher heat inputs. Corus should be consulted for advice in this circumstance. See back cover for contact details.

HAZ properties

Fabrication specifications commonly set limits on HAZ hardness levels. Various methods may be employed for predicting the peak hardness values for welded joints. HAZ toughness is another important aspect of weld procedure testing; it is measured by Charpy V-notch impact and CTOD tests. A minimum value of HAZ toughness is commonly set in fabrication specifications.

Guidance on the selection of preheat and weld heat input to achieve specific HAZ properties is available from Corus on request.

Avoidance of HAZ cracking

The presence of hydrogen in combination with stresses in the weld joint is the main reason for HAZ cracking. The risk of HAZ cracking can be minimised by:

- Pre-heating the parent material before welding. The table on the next page gives general guidance for pre-heating.
- Selecting consumables with low hydrogen content. For offshore applications it is recommended to have a maximum consumable hydrogen level of 5 ml/100g weld metal.
- Ensuring that the joint surfaces are perfectly clean and dry.
- Minimising the shrinkage stresses by ensuring a good fit between the workpieces and a planned sequence of weld runs (balanced welding).

For further advice on avoidance of HAZ cracking refer to British Standard BS EN1011-2:2001 (replacement for BS5135:1994) or contact Corus who will be happy to give advice on specific situations.

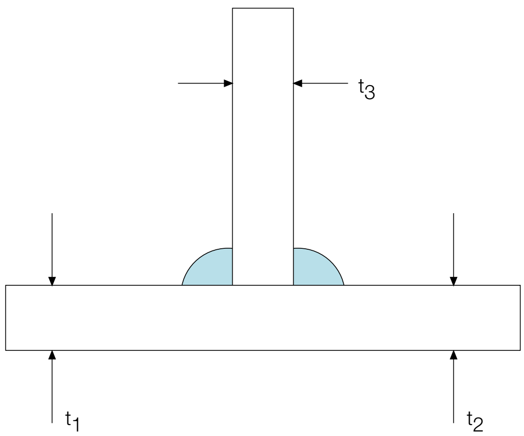
Pre-heat recommendations for the avoidance of HAZ cracking

The section below is intended as illustration of the pre-heat requirements for general applications. Corus can provide detailed guidance on pre-heating requirements for individual circumstances. In the majority of cases it is recommended that the interpass temperatures should be kept below 250°C.

The following is a guideline derived from a computer model which assumes the following conditions: the weld is a fillet weld of three equal thicknesses, i.e. the combined joint thicknesses is 3t, with a 5ml/100g consumable hydrogen level. The resultant suggested pre-heat should be used for the thicker section sizes and/or when restraint is high.

<table>
<tr><th colspan="3">Example data</th><th colspan="7">Heat input / kJ/mm</th></tr>
<tr><th>Grade</th><th>t / mm</th><th>CEV / wt%</th><th>0.8</th><th>1.0</th><th>1.5</th><th>2.0</th><th>2.5</th><th>3.5</th><th>5.0</th></tr>
<tr><td>355 TMCR</td><td>t ≤ 20</td><td>0.32</td><td>30</td><td></td><td colspan="5" rowspan="2">room temperature</td></tr>
<tr><td></td><td>20 < t ≤ 65</td><td>0.35</td><td>50</td><td>35</td></tr>
<tr><td>355 NORM</td><td>t ≤ 40</td><td>0.39</td><td>75</td><td>65</td><td>35</td><td colspan="3" rowspan="2">room temperature</td><td rowspan="7">N/A</td></tr>
<tr><td></td><td>40 < t ≤ 120</td><td>0.39</td><td>75</td><td>65</td><td>35</td></tr>
<tr><td>420/450/460 RQT</td><td>6 ≤ t < 16</td><td>0.38</td><td>55</td><td>40</td><td colspan="4" rowspan="4">room temperature</td></tr>
<tr><td></td><td>16 ≤ t < 30</td><td>0.34</td><td>45</td><td>30</td></tr>
<tr><td></td><td>30 ≤ t < 40</td><td>0.37</td><td>60</td><td>45</td></tr>
<tr><td></td><td>40 ≤ t < 60</td><td>0.38</td><td>60</td><td>45</td></tr>
<tr><td></td><td>60 ≤ t ≤ 100</td><td>0.40</td><td>70</td><td>55</td><td>25</td><td colspan="3"></td></tr>
<tr><td colspan="3"></td><td colspan="7">Figures are pre-heat, °C</td></tr>
</table>

The combined joint thickness is the sum of the parent metal thickness averaged over a distance of 75mm from the weld line, i.e. $t_1+t_2+t_3$ as shown schematically in the figure, for the purpose of the above table $t=t_1=t_2=t_3$.

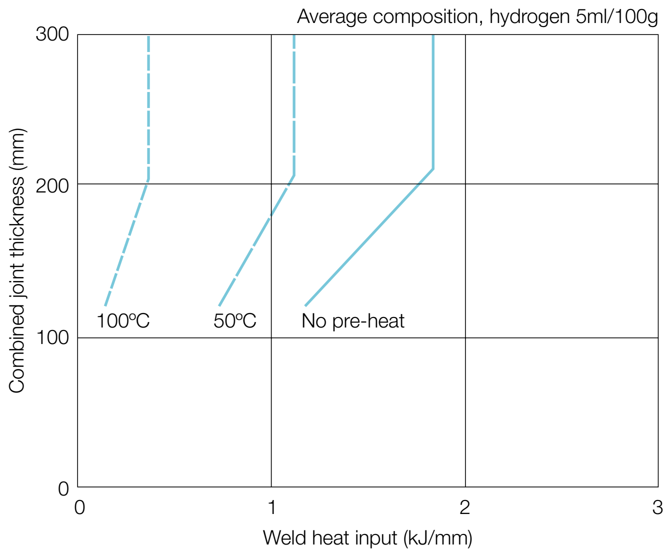


Weld metal cracking

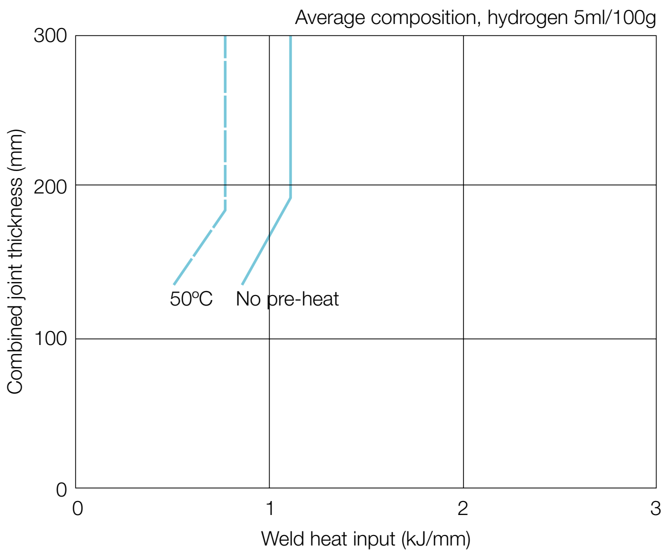
The pre-heat recommendations given above are based solely on the considerations for avoiding HAZ cracking. Due to developments in steel processing it is now possible to achieve strength levels at lower CEV which enables a lower pre-heat to be recommended based on the HAZ. In some instances however, the scope for lowering pre-heat may be limited due to the risk of weld metal cracking.

For further guidance regarding this topic contact the consumable manufacturer. Alternatively Corus can provide assistance on request.

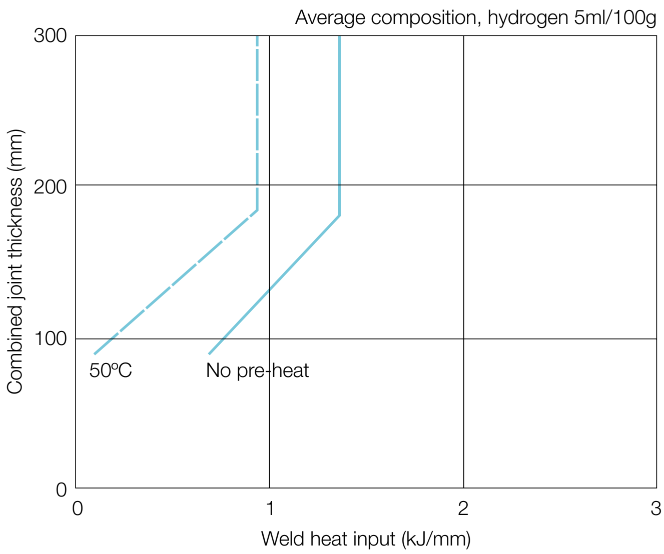
BS7191 grade 355 normalised



BS7191 grade 350/355 TMCR



BS7191 grade 450 quenched and tempered



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