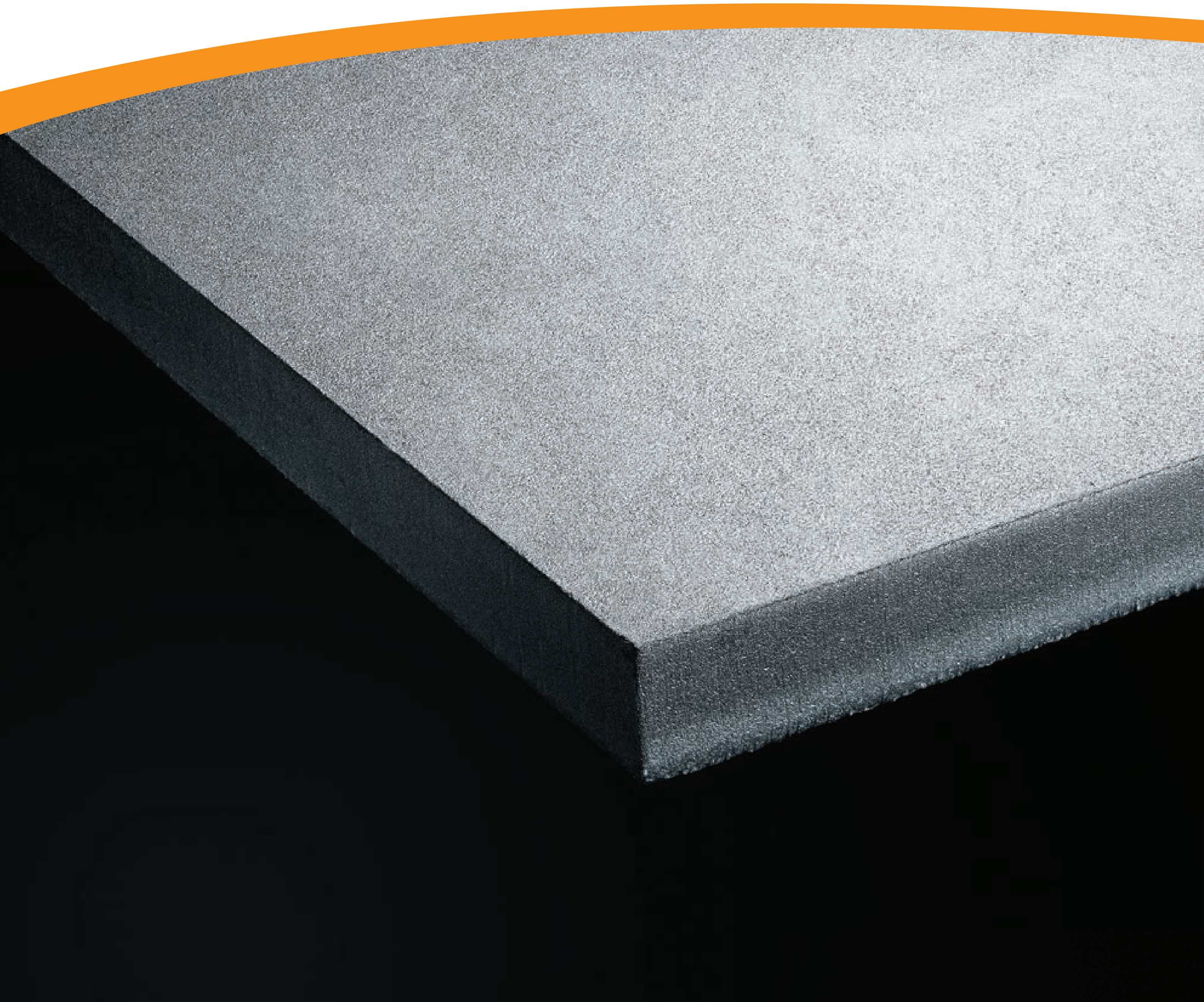
TATA STEEL

TATA

RQT® technical guide

High strength quenched and tempered structural steel.



Contents

RQT®

High strength quenched and tempered structural steel.

The RQT range of steels have been developed for applications where high strength and outstanding toughness are necessary, such as mining and quarrying, process industry, material handling, construction and earthmoving.

This technical guide provides data for our range of RQT steels. This guide provides all the essential operating parameters for the use of RQT steel in the manufacturing process.

Designers and plant operators strive to reduce weight and increase efficiency of plant and equipment. There are substantial benefits to be achieved by employing high strength RQT steels for maximum structural performance in extreme environments.

Tata Steel works in partnership with customers, tailoring products and services to suit their applications, delivering value improvement through the use of Tata Steel plate.

We offer a range of specialist technical support which is available to assist with any specific application or process. For further details please contact our technical advice service listed at the back of this brochure.

TATA STEEL

Tata Steel is one of Europe's largest steel producers. We serve many different and demanding markets worldwide, including lifting and excavating, aerospace, automotive, construction, energy & power, and packaging. Our primary steelmaking operations in the UK and the Netherlands are supported by a global sales and distribution network.

Our European operations are a subsidiary of Tata Steel Group, one of the world's top ten steel producers. With a worldwide presence, the Tata Steel Group, including the Europe operations, Tata Steel Thailand and NatSteel Asia, has approximately 80,000 employees across five continents and a aggregate crude steel production capacity of over 28 million tonnes.

Innovation and continuous improvement are at the heart of our performance culture. We aim to create value by offering a sustainable and value-added steel product range supported by unrivalled customer service. By working in partnership with you, we find the best solutions to meet your needs and help your business to perform.

RQT®

Tata Steel offer a range of RQT grades designed for high performance in service and ease of fabrication. Close control of chemistry ensures RQT steels are readily weldable in accordance with the guidelines in this brochure.

Table 1. Chemical analysis

	Thickness (mm)	Max. C (%)	Max. Si (%)	Max. Mn (%)	Max. S (%)	Max. P (%)	Max. Cr (%)	Max. Mo (%)	Max. V (%)	Max. Ni (%)	Max. Al (%)	Max. Nb (%)	Max. B (%)
RQT 501	8 ≤ t ≤ 100	0.20	0.60	1.60	0.010	0.025		0.60	0.10	1.00	0.06		
RQT 601	8 ≤ t ≤ 80	0.20	0.50	1.60	0.010	0.020	1.00	0.60	0.08	1.00		0.06	0.0040
RQT 701	8 ≤ t ≤ 130	0.20	0.50	1.60	0.010	0.020	1.00	0.70	0.08	1.50		0.06	0.0040
RQT 901	8 ≤ t ≤ 65	0.20	0.50	1.60	0.010	0.020	1.00	0.70	0.08	1.50		0.06	0.0040

Table 2. Carbon equivalent

	Thickness (mm)	Max. CEV	Typical CET
RQT 501	8 ≤ t ≤ 100	0.41	0.32
RQT 601	8 < t ≤ 30	0.43	0.33
	30 < t ≤ 50	0.55	0.37
	50 < t ≤ 80	0.55	0.38
RQT 701	8 ≤ t ≤ 30	0.43	0.33
	30 < t ≤ 60	0.55	0.37
	60 < t ≤ 100	0.58	0.38
	100 < t ≤ 130	0.61	0.38
RQT 901	8 ≤ t ≤ 65	0.58	0.38

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

$$CET = C + \frac{Mn+Mo}{10} + \frac{Cu+Cr}{20} + \frac{Ni}{40}$$

Testing in accordance with EN ISO 6892, EN ISO 148-1 and EN ISO 6506.

Table 3. Mechanical properties

	Thickness (mm)	Min. yield strength (MPa)	Tensile strength (MPa)	Min. elongation on 50mm gauge length (%)	Min. average impact energy* (J at -40°C)	Min. individual impact energy* (J at -40°C)
RQT 501	8 ≤ t ≤ 50	470	560 - 710	21	30	21
	50 < t ≤ 80	430	530 - 700	21	30	21
	80 < t ≤ 100	415	530 - 700	21	30	21
RQT 601	8 ≤ t ≤ 50	620	690 - 850	19	30	21
	50 < t ≤ 80	550	670 - 850	19	30	21
RQT 701	8 ≤ t ≤ 70	690	790 - 930	18	30	21
	70 < t ≤ 130	630	690 - 930	18	30	21
RQT 901	8 ≤ t ≤ 50	890	940 - 1100	11	30	21
	50 < t ≤ 65	830	880 - 1100	11	30	21

Testing in accordance with EN ISO 6892, EN ISO 148-1 and EN ISO 6506.
*For plate thicknesses below 12.5mm, reduced section Charpy test pieces are used with proportionate reduction of energy values.
Longitudinal charpy V notch 2mm sub surface.

Mechanical properties in accordance with EN10025-6:2004 and ASTM A 514/A154M-05 are available on request. Please contact us with your specific requirements.

RQT® 501 DIMENSIONS

Size availability guide

The information in this table must be read in conjunction with the explanatory notes at the bottom of page 7.
Figures within the table are maximum lengths in metres.

	Plate width (mm)												
Plate thickness (mm)	**≥1220 ≤1250**	**>1250 ≤1300**	**>1300 ≤1500**	**>1500 ≤1600**	**>1600 ≤1750**	**>1750 ≤1800**	**>1800 ≤2000**	**>2000 ≤2100**	**>2100 ≤2250**	**>2250 ≤2500**	**>2500 ≤2750**	**>2750 ≤3000**	**>3000 ≤3050**
8	12	12	12	12	12	12	12	12	12	12			
9	12	12	12	12	12	12	12	12	12	12			
10	12	12	12	12	12	12	12	12	12	12			
12	12	12	12	12	12	12	12	12	12	12	12	12	12
12.5	15	15	15	15	15	15	15	15	15	15	15	15	15
15	15	15	15	15	15	15	15	15	15	15	15	15	15
20	15	15	15	15	15	15	15	15	15	15	15	15	15
25	15	15	15	15	15	15	15	15	15	15	15	15	15
30	15	15	15	15	15	15	15	15	15	15	15	15	15
35	15	15	15	15	15	15	15	15	15	15	15	15	15
40	15	15	15	15	15	15	15	15	15	15	15	14.5	13
45	12	12	12	12	12	12	12	12	12	12	12	12	11.5
50	12	12	12	12	12	12	12	12	12	12	12	11.5	10.5
55	11.5	11.5	11	12	12	12	12	12	12	12	11.5	10.5	9.5
60	10.5	10.5	10	12	12	12	11.5	12	12	11.5	10.5	9.5	8.5
65	10	9.5	9	12	12	11	10.5	12	11.5	10.5	9.5	8.5	8
70	9	9	8.5	12	11	10.5	10	11	10.5	10	9	8	7.5
75	8.5	8.5	8	11	10.5	9.5	9.5	10.5	10	9.5	8.5	7.5	7
80	8	8	7.5	10.5	10	9	8.5	10	9.5	8.5	8	7	6.5
90				9.5	8.5	8	7.5	8.5	8	7.5	7	6	5.5
100				8.5	8	7	7	8	7.5	7	6	5.5	5

RQT® 601 AND RQT® 701 DIMENSIONS

Size availability guide

The information in this table must be read in conjunction with the explanatory notes at the bottom of the page 7.
Figures within the table are maximum lengths in metres.

	Plate width (mm)												
Plate thickness (mm)	**≥1220 ≤1250**	**>1250 ≤1300**	**>1300 ≤1500**	**>1500 ≤1600**	**>1600 ≤1750**	**>1750 ≤1800**	**>1800 ≤2000**	**>2000 ≤2100**	**>2100 ≤2250**	**>2250 ≤2500**	**>2500 ≤2750**	**>2750 ≤3000**	**>3000 ≤3050**
8	12	12	12	12	12	12	12	12	12	12			
9	12	12	12	12	12	12	12	12	12	12			
10	12	12	12	12	12	12	12	12	12	12			
12	12	12	12	12	12	12	12	12	12	12	12	12	12
12.5	15	15	15	15	15	15	15	15	15	15	15	15	15
15	15	15	15	15	15	15	15	15	15	15	15	15	15
20	15	15	15	15	15	15	15	15	15	15	15	15	15
25	15	15	15	15	15	15	15	15	15	15	15	15	15
30	15	15	15	15	15	15	15	15	15	15	15	15	15
35	15	15	15	15	15	15	15	15	15	15	15	15	15
40	15	15	15	15	15	15	15	15	15	15	15	14.5	13
45	12	12	12	12	12	12	12	12	12	12	12	12	11.5
50	12	12	12	12	12	12	12	12	12	12	12	11.5	10.5
55	11.5	11.5	11	12	12	12	12	12	12	12	11.5	10.5	9.5
60	10.5	10.5	10	12	12	12	11.5	12	12	11.5	10.5	9.5	8.5
65	10	9.5	9	12	12	11	10.5	12	11.5	10.5	9.5	8.5	8
70	9	9	8.5	12	11	10.5	10	11	10.5	10	9	8	7.5
75	8.5	8.5	8	11	10.5	9.5	9.5	10.5	10	9.5	8.5	7.5	7
80	8	8	7.5	10.5	10	9	8.5	10	9.5	8.5	8	7	6.5
90				9.5	8.5	8	7.5	8.5	8	7.5	7	6	5.5
100				8.5	8	7	7	8	7.5	7	6	5.5	5
110	Please contact us with your requirements												
120	Please contact us with your requirements												
130	Please contact us with your requirements												

RQT® 901 DIMENSIONS

Size availability guide

The information in this table must be read in conjunction with the explanatory notes at the bottom of this page.
Figures within the table are maximum lengths in metres.

	Plate width (mm)												
Plate thickness (mm)	**≥1220 ≤1250**	**>1250 ≤1300**	**>1300 ≤1500**	**>1500 ≤1600**	**>1600 ≤1750**	**>1750 ≤1800**	**>1800 ≤2000**	**>2000 ≤2100**	**>2100 ≤2250**	**>2250 ≤2500**	**>2500 ≤2750**	**>2750 ≤3000**	**>3000 ≤3050**
8	12	12	12	12	12	12	12	12	12	12			
9	12	12	12	12	12	12	12	12	12	12			
10	12	12	12	12	12	12	12	12	12	12			
12	12	12	12	12	12	12	12	12	12	12	12	12	12
12.5	15	15	15	15	15	15	15	15	15	15	15	15	15
15	15	15	15	15	15	15	15	15	15	15	15	15	15
20	15	15	15	15	15	15	15	15	15	15	15	15	15
25	15	15	15	15	15	15	15	15	15	15	15	15	15
30	15	15	15	15	15	15	15	15	15	15	15	15	15
35	15	15	15	15	15	15	15	15	15	15	15	15	15
40	15	15	15	15	15	15	15	15	15	15	15	14.5	13
45	12	12	12	12	12	12	12	12	12	12	12	12	11.5
50	12	12	12	12	12	12	12	12	12	12	12	11.5	10.5
55	11.5	11.5	11	12	12	12	12	12	12	12	11.5	10.5	9.5
60	10.5	10.5	10	12	12	12	11.5	12	12	11.5	10.5	9.5	8.5
65	10	9.5	9	12	12	11	10.5	12	11.5	10.5	9.5	8.5	8

Notes on size tables

There will be occasions when sizes and grades may be manufactured which are not shown in the individual grade tables. As a guide to the available plate sizes for an intermediate gauge (e.g. 18mm), please use the nearest gauge shown in the individual grade tables (i.e. 20mm).
Plate widths up to 3200mm wide are available on request. Please contact us with your specific requirements.

Notes

- Please refer to the RQT data in this technical guide for maximum thickness for each specific grade.
- For plate sizes greater than 100mm please contact us to discuss your specific requirements

Disclaimer

The welding information contained within this brochure, is for guidance only. The preheat suggestions are from EN 1011-2:2001and are based on 3 dimensinal heat flow, for a maximum cast CEV. It is possible that for many cases a lower preheat could be employed to prevent hydrogen cracking. A qualified welding procedure should always be used to ensure that optimum welding conditions are employed.

FABRICATION GUIDE

Shearing

RQT 501 can be cold sheared. The maximum gauge that can be handled will depend on the power available in the shear unit and the shear blade material. For smaller shears the maximum thickness should be reduced dependant on the grade. Table 4 lists the reduction in thickness required compared to S355JR grade material.

Table 4: Shearing thickness reduction compared to S355JR material

RQT 501	20%
RQT 601	30%
RQT 701	35%
RQT 901	50%

Flame cutting

RQT steels can be cut satisfactorily using conventional oxy-fuel gas practices, without the need for preheat, provided cutting procedures are selected with consideration of the plate thickness and the CEV. Other cutting techniques such as abrasive water jet, where no heat is generated, or plasma cutting techniques, which gives a smaller HAZ than oxy-fuel gas, can be used. Care should be taken when cutting underwater as the quenching effect could result in a high hardness edge forming. With all the thermal cutting processes care should be taken that cut edges are free from sharp notches.

Tata Steel will be pleased to offer advice for your specific requirements.

Cold bending

The RQT range of steels can be readily cold formed. The power required for forming RQT 501 will be appreciably higher than that for S355 of the same thickness. It is recommended that the largest possible bending radius should be used, and generally the inside radius should not be less than the limits described in table 5.

Table 5: Minimum cold bending radius

	Radius	Power needed compared to S355
RQT 501	3T	150%
RQT 601	3T	160%
RQT 701	3T	170%
RQT 901	3T	190%

Hot forming

It is recommended that RQT steels are NOT hot formed. Where hot forming is absolutely necessary, by design codes, the steel should be heated to a temperature at least 50°C below the tempering temperature stated on the certificate. In all cases hot forming temperatures should not exceed 550°C. When temperatures greater than 450°C are used, the soaking time should be minimised as far as possible to prevent deterioration in mechanical properties.

Stress relief

In cases where stress relief is considered necessary after welding, the stress relieving temperature should be at the lowest temperature consistent with requirements and at least 20°C below the tempering temperature stated on the test certificate. Stress relaxation tests have indicated that adequate stress relief can be obtained from a soaking time of 60min at 550°C. Prolonged time at temperature in excess of 550°C is not generally recommended since it can cause some deterioration in mechanical properties.

Machining

RQT 501 can be readily machined and drilled using high speed steel (HSS) or cemented carbide drills. The hardness of RQT 501 can be approximated as 1/3rd of the tensile strength stated on the test certificate.

Welding

RQT steels can be readily welded with appropriate preheat. As a guide the following temperatures are recommended for a conventional butt weld of identical thickness. For further information refer to our fabrication guide.

Maximum recommended interpass temperatures should not exceed 250°C.

Tolerances

The manufacturing tolerances are in compliance with EN10029:1991. Surface quality is compliant with EN10163:2004 class A subclass 1. Other tolerances are available by agreement.

Table 6. Weld preheat

Combined thickness (mm)	10	20	30	40	50	60	70	80	90	100	100+
RQT 501	20	20	20	20	20	20	20	20	20	20	20
RQT 601	20	20	20	20	20	20	150	150	175	175	175
RQT 701	20	20	20	20	20	20	20	20	175	175	200
RQT 901	20	20	20	125	125	150	175	175	175	175	200

WELDING GUIDE

The Roller Quench and Tempered series of steels combine high yield and tensile strengths with good notch toughness, they have excellent weldability, and high integrity welded joints can be made in all of the RQT grades. The following are important factors when making welds in RQT steels.

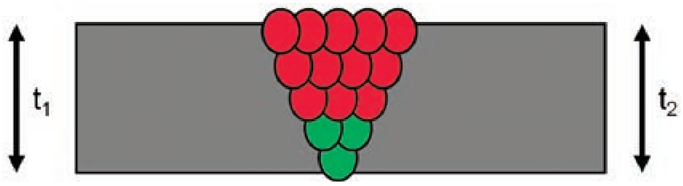
Joint Design

Joint design and good workmanship are needed to take advantage of the high strength of Q&T steels and to optimize the serviceability of weldments made in them. Abrupt changes in cross section or stress raisers in regions of high stress are detrimental in very high strength steels.

Stress raisers, such as those most commonly found at the toes of improperly contoured welds are of great concern. Weld metal should blend smoothly with the parent meal at the toes and the root of the weld. Excessive weld reinforcement should be avoided.
A contributing factor in hydrogen cracking are the stresses within the weld joint area. Try to minimize these stresses.

Do not use a welding consumable that has a strength that is far greater than the parent plate. Use a welding consumable that matches or slightly overmatches the strength of the parent steel. Using a weld metal that undermatches the parent plate can be beneficial. Such a weld metal will have higher toughness, higher resistance to hydrogen cracking and lower residual stresses in the weld joint.

In butt welds it can be beneficial to make the root run and possibly the second layer of runs, with an undermatched welding consumable. The fill passes can be made with matching strength weld metal.



Weld consumable with matched strength to the parent material.

Tack welds, root passes and the first few fill passes should be welded with lower strength weld metal.

Preheat and Welding Heat Input

The strength and toughness of the heat affected zone (HAZ) of welds in quench and tempered steels are related to the cooling rate, the time taken to cool between 800°C and 500°C (t8/5). The fairly rapid dissipation of welding heat is needed to retain adequate strength and toughness. The deposition of many small beads improved the notch toughness of the weld by grain refining and the tempering action of ensuring passes. Welding heat is dissipated more rapidly into a thick cross section of steel than into a thin one. For this reason, the maximum heat input can be increased as the joint thickness increases.

It maybe necessary to use preheat to prevent hydrogen cracking either in the parent steel or the weld metal. However, preheat should be used with caution as it reduces the cooling rate of the weld heat affected zone. Too slow a cooling rate and the resulting HAZ microstructure can have reduced strength and poor toughness.

* The preheats shown on pages 4 - 7 are based on parent plate compositions. It is possible that some welding consumables have a higher CEV than the parent plate. In such a case the degree of preheat should be based on the highest CEV.

Welding consumables

The following preheating guidance is derived from tables in EN1011-2 2001 and are based on a fillet weld between members of a similar thickness.

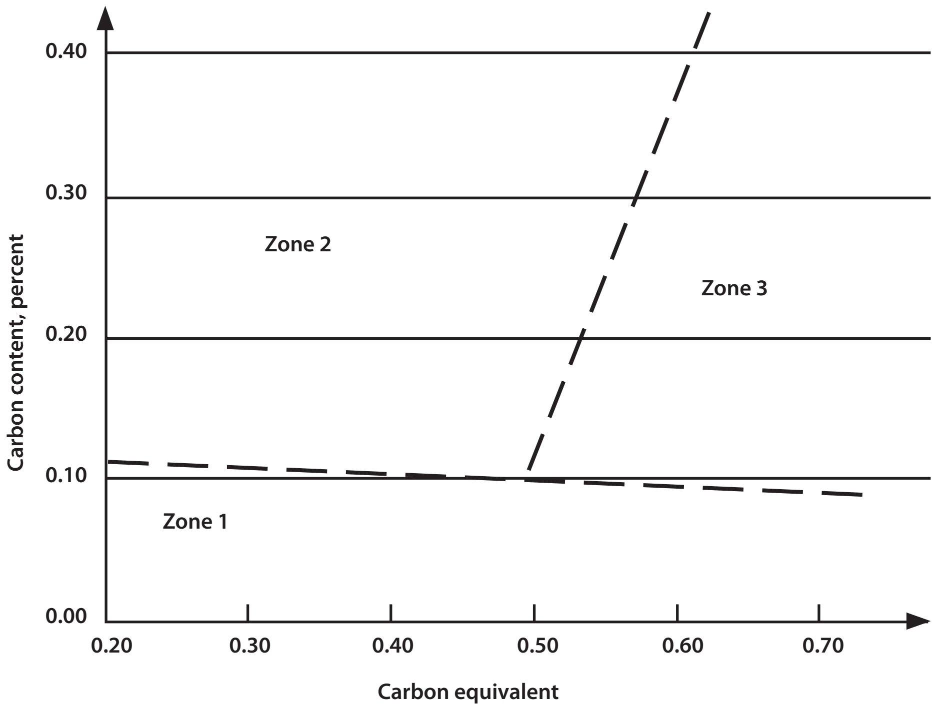
They are based on a welding heat input of 1.5 kJ/mm and a scale C, diffusible hydrogen content of 5 – 10 ml/100g weld metal. The carbon equivalent is taken as the maximum ladle composition. Plates with a lower CEV may allow the use of a lower preheating temperature.

For welds made between members of unequal thickness and/or different grades and chemistries, preheating should be based on combined thickness and greatest CEV of the different components.

Welding procedure approval tests should be carried out to ensure the required mechanical properties are attained.

Hydrogen cracking.

As with all higher strength steels, RQT steels can be susceptible to hydrogen cracking, also known as 'cold cracking' and 'delayed cracking'. The chart below shows that as carbon and carbon equivalent increases then the greater the possibility of cracking occurring.



Zone 1
Cracking is unlikely but may occur with high hydrogen or high restraint.

Zone 2
Cracking could occur. Prevention is based on controlling the cooling rate to stop HAZ hardness reaching a critical value. This could be achieved by judicious use of welding heat input and/or preheat

Zone 3
Risk of cracking. Low hydrogen welding techniques required. Preheat should be determined for the welding heat input to be used.

Carbon equivalent (CEV) can be calculated from;

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

The risk of hydrogen cracking can be reduced by:

1. Remove potential sources of hydrogen.
2. Control the welding heat input and
3. Use preheat

Remove potential sources of hydrogen.

- Clean the weld joint area to shiny steel i.e. remove all traces of rust and scale. Degrease the weld area to remove traces of (machining) lubricant and wax (marking) crayons.

- Preheat the whole of the weld area if necessary . This removes moisture as well as prevents any remaining hydrogen from building up into high levels in a possible susceptible microstructure that could form during welding.

- Use low hydrogen welding practice. If using the Manual Metal Arc (MMA) process then bake and store the electrodes according to the manufacturers instructions. If using Submerged Arc Welding (SAW), Metal or Flux Cored Arc Welding (MCAW / FCAW) then ensure that the consumables have been stored in a dry environment. Do not use them if they are showing signs of rust forming on them.

Arc Energy (AE) can be calculated from:

$$\mathbf{AE = \frac{V \times A \times 60}{s \times 1000}}$$

where V = potential difference (volt)
A = current (amp)
s = welding speed (mm/min)

From this the welding Heat Input (HI) can be calculated from:

HI = AE x k

where k is the thermal efficiency factor

For the different welding processes the thermal efficiency factor is:

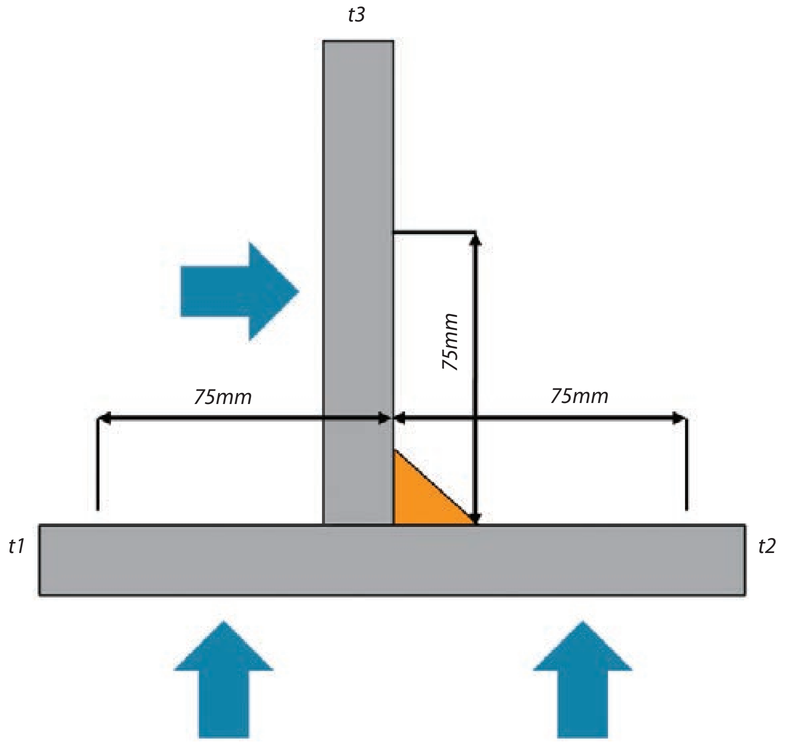
Process	k
SAW	1.0
MMA	0.8
MIG	0.8
FCAW	0.8
MCAW	0.8
TIG	0.6

Combined thickness for preheat

Refer to preheat tables on pages 4 to 7

Fillet weld

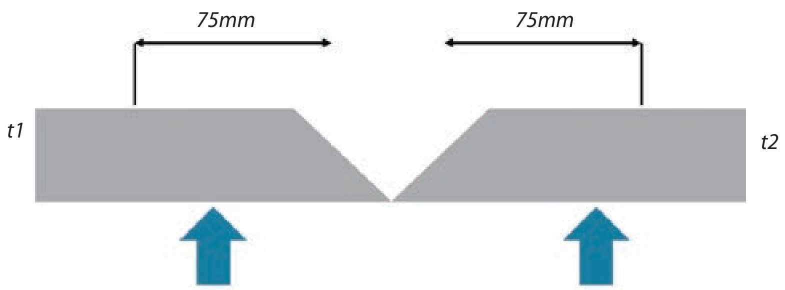
Combined thickness = t1 + t2 + t3



In accordance with EN1011-2, Preheat to extend 75mm either side of the weld centreline

Butt weld

Combined thickness = t1 + t2



In accordance with EN1011-2, Preheat to extend 75mm either side of the weld centreline

Welding consumables

Welding consumables for welding processes commonly used in fabrication are available with matching strengths for the RQT series of steel. Your consumable supplier will be able to recommend a suitable electrode.

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Tata Steel Europe Limited is registered under number 05957565 with registered office at 30 Millbank, London, SW1P 4WY.

English Version 02:2012 (metric)