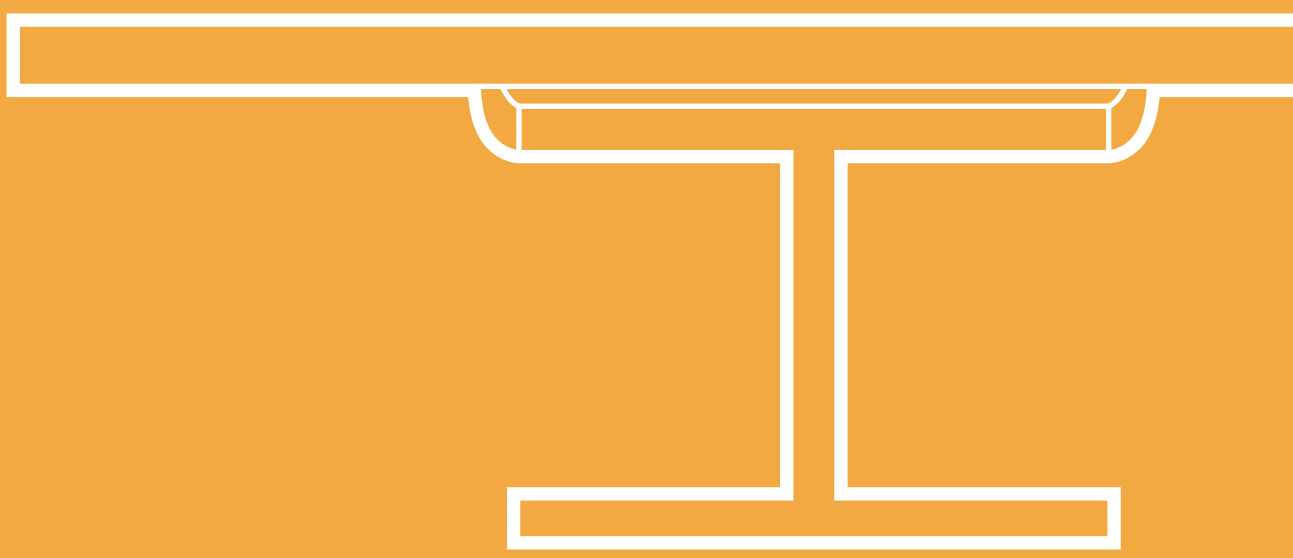
Corus Construction & Industrial

Steel plates for offshore structural applications

Primary structural steel plate
355, 420, 450 and 460 grades



Corus manufactures high quality offshore steel plates satisfying a range of National, International and individual oil company specifications.

Corus manufactures offshore structural steels to the following offshore standards: BS7191:1989 grades 355EM/EMZ and 450EM/EMZ, API 2H/2W/2Y grades 50 and 60, and to individual project specifications as required. Corus also manufactures offshore steels to the new European standard EN 10225. Shipbuilding plate for floating solutions and FPSO's are also supplied to all major shipbuilding Classification Society standards.

This brochure describes primary structural steels with nominal minimum yield strengths of 355 MPa, 420 MPa, 450 MPa and 460 MPa, with chemistries developed for offshore use. The brochure "A guide to fabrication of primary structural steel plate" is available and outlines procedures for welding and fabrication.

Specifications and standards

The following summarises chemical and mechanical property requirements from three typical offshore steel specifications (BS7191, EN 10225, API 2H/2W/2Y) and are given as examples of conditions to be achieved.

British Standard BS 7191:1989

BS 7191: Grade 355 Chemical Composition (ladle and product analysis / wt%) (1)

	C max.	Si	Mn	S max.	P max.	Cr max.	Mo max.	Nb max.	V max.	Ti max.	Ni max.	Cu max.	Al(tot) max.	N max.
EM	0.15	0.25/0.55	1.00/1.65	0.015	0.025	0.25	0.08	0.04	0.015	0.02	0.45	0.3	0.055	0.01
EMZ	0.15	0.25/0.55	1.00/1.65	0.008	0.02	0.25	0.08	0.04	0.01	0.02	0.45	0.3	0.05	0.01

Minimum Yield Strength / MPa
t ≤16 mm 355
16 < t ≤40 mm 345
40 < t ≤63 mm 340
63 < t ≤100 mm 325
100 < ≤120 mm 315
120 < ≤150 mm 305

Tensile Strength / MPa
460 - 620

Minimum Average Charpy-V Impact Energy /J @ -40°C
50

mid-thickness tests also required for t >40 mm

Maximum CEV (wt%)
t ≤40 mm 0.43
40 < t ≤75 mm 0.44
75 < t ≤150 mm 0.45

(1) Other restrictions apply beyond those shown.

BS 7191: Grade 450 Chemical Composition (ladle and product analysis / wt%) (1)

	C max.	Si	Mn	S max.	P max.	Cr max.	Mo max.	Nb max.	V max.	Ti max.	Ni max.	Cu max.	Al(tot) max.	N max.
EM	0.16	0.25/0.60	1.00/1.65	0.015	0.025	0.3	0.25	0.03	0.08	0.02	0.65	0.3	0.055	0.01
EMZ	0.16	0.25/0.60	1.00/1.65	0.008	0.025	0.3	0.25	0.03	0.08	0.02	0.65	0.3	0.055	0.01

Minimum Yield Strength / MPa
t ≤16 mm 450
16 < t ≤25 mm 430
25 < t ≤75 mm 415

Tensile Strength / MPa
550 - 700

Minimum Average Charpy-V Impact Energy /J @ -40°C
60

mid-thickness tests also required for t >40 mm

Maximum CEV (wt%)
t ≤75 mm 0.43

(1) Other restrictions apply beyond those shown.

European Standard EN 10225

EN 10225: S355 Grades Chemical Composition (ladle and product analysis / wt%) (1)

	C max.	Si	Mn	S max.	P max.	Cr max.	Mo max.	Nb max.	V max.	Ti max.	Ni max.	Cu max.	Al(tot)	N max.
S355G7+M S355G7+N	0.14	0.15/0.55	1.00/1.65	0.01	0.02	0.25	0.08	0.04	0.06	0.025	0.5	0.3	0.015/0.055	0.01
S355G8+M S355G8+N	0.14	0.15/0.55	1.00/1.65	0.007	0.02	0.25	0.08	0.04	0.06	0.025	0.5	0.3	0.015/0.055	0.01
S355G9+M S355G9+N	0.12	0.15/0.55	1.65 max.	0.01	0.02	0.2	0.08a	0.03	0.06	0.025	0.7b	0.3	0.015/0.055	0.01
S355G10+M S355G10+N	0.12	0.15/0.55	1.65 max.	0.005	0.015	0.2	0.08a	0.03	0.06	0.025	0.7b	0.3	0.015/0.055	0.01

a. For t> 75 mm maximum Mo of 0.20% shall apply for +M condition.
b. For t> 40 mm the minimum Ni content shall be 0.30%.

Minimum Yield Strength / MPa		Tensile Strength / MPa		Minimum Average Charpy-V Impact Energy / J @ -40°C
t ≤16 mm	355	t ≤100 mm	470 - 630	50
16 < t ≤25 mm	355	t >100 mm	460 - 620	
25 < t ≤40 mm	345		(+N only)	mid-thickness tests also required for t > 40 mm
40 < t ≤63 mm	335			
63 < t ≤100 mm	325	**Minimum Elongation (5.65 $\sqrt{s_o}$) / %**		
120 < t ≤150 mm	320 (+N only)	22		

(1) Other restrictions apply beyond those shown.

EN 10225: S420 Grades Chemical Composition (ladle and product analysis / wt%) (1)

	C max.	Si	Mn max.	S max.	P max.	Cr max.	Mo max.	Nb max.	V max.	Ti max.	Ni max.	Cu max.	Al(tot)	N max.
S420G1+Q	0.14a	0.15/0.55	1.65	0.01	0.02	0.25	0.25	0.04	0.08	0.02	0.7	0.3	0.015/0.055	0.01
S420G2+Q	0.14a	0.15/0.55	1.65	0.007	0.02	0.25	0.25	0.04	0.08	0.02	0.7	0.3	0.015/0.055	0.01

a. A maximum carbon value of 0.15% is permitted for thicknesses less than 15 mm.

Minimum Yield Strength / MPa		Tensile Strength / MPa		Minimum Average Charpy-V Impact Energy / J @ -40°C
t ≤16 mm	420	t ≤40 mm	550 - 660	60
16 < t ≤40 mm	400	40 < t ≤100 mm	480 - 640	
40 < t ≤63 mm	390			mid-thickness tests also required for t > 40 mm
63 < t ≤80 mm	380	**Minimum Elongation (5.65 $\sqrt{s_o}$) / %**		
80 < t ≤100 mm	380	19		

(1) Other restrictions apply beyond those shown.

EN 10225: S460 Grades Chemical Composition (ladle and product analysis / wt%) (1)

	C max.	Si	Mn max.	S max.	P max.	Cr max.	Mo max.	Nb max.	V max.	Ti max.	Ni max.	Cu max.	Al(tot)	N max.
S460G1+Q	0.14a	0.15/0.55	1.65	0.01	0.02	0.25	0.25	0.04	0.08	0.02	0.7	0.3	0.015/0.055	0.01
S460G2+Q	0.14a	0.15/0.55	1.65	0.007	0.02	0.25	0.25	0.04	0.08	0.02	0.7	0.3	0.015/0.055	0.01

a. A maximum carbon value of 0.15% is permitted for thicknesses less than 15 mm.

Thickness	Minimum Yield Strength / MPa	Tensile Strength / MPa	Minimum Elongation (5.65 $\sqrt{s_o}$) / %
t ≤16 mm	460	540 - 700	17
16 < t ≤25 mm	440	530 - 690	
25 < t ≤40 mm	420	520 - 680	**Minimum Average Charpy-V Impact Energy / J @ -40°C**
40 < t ≤63 mm	415	515 - 675	60
63 < t ≤80 mm	405	505 - 665	
80 < t ≤100 mm	400	500 - 660	mid-thickness tests also required for t > 40 mm

(1) Other restrictions apply beyond those shown.

API specifications API 2H/2W/2Y: 1993

Grade 50 Chemical Composition (ladle analysis/wt%) (1)

	C max.	Si	Mn	S max.	P max.	Cr max.	Mo max.	Nb	V max.	Ti	Ni max.	Al(tot)	N max.
API 2H 50	0.18	0.05/0.40	1.15/1.60	0.01	0.03		0.2	0.01/0.04	nda	0.02max.	0.45	0.02/0.06	0.012
API 2W 50/50T	0.16	0.05/0.50	1.15/1.60	0.01	0.03	0.25	0.08	0.03max.	nda	0.003/0.02	0.75	0.02/0.06	0.012

nda: no deliberate addition without the specific approval of the purchaser.

API 2H	**Minimum Yield Strength / MPa**	**Tensile Strength / MPa**	**Minimum Elongation (in 2") / %**	**Minimum Average Charpy-V Impact Energy / J @ -40ºC**
	t ≤63.5 mm 345 t >63.5 mm 324	t ≤100 mm 483 - 620	23	41

API 2W	**Yield Strength / MPa**	**Minimum Tensile Strength / MPa**	**Minimum Elongation (in 2") / %**	**Minimum Average Charpy-V Impact Energy / J @ -40ºC**
Grade 50	t ≤25 mm 345 - 517 t >25 mm 345 - 483	t ≤100 mm 448	23	41
Grade 50T	t ≤25 mm 345 - 552 t >25 mm 345 - 517	t ≤100 mm 483	23	41

(1) Other restrictions apply beyond those shown.

Grade 60 Chemical Composition (ladle analysis/wt%) (1)

	C max.	Si	Mn	S max.	P max.	Cr max.	Mo max.	Nb max.	V max.	Ti	Ni max.	Al(tot)	N max.
API 2Y 60	0.16	0.05/0.50	1.15/1.60	0.01	0.03	0.25	0.15	0.03	nda	0.003/0.02	1.0	0.02/0.06	0.012

nda: no deliberate addition without the specific approval of the purchaser.

API 2W	**Yield Strength / MPa**	**Minimum Tensile Strength / MPa**	**Minimum Elongation (in 2") / %**	**Minimum Average Charpy-V Impact Energy / J @ -40ºC**
	t ≤25 mm 414 - 621 t >25 mm 414 - 586	t ≤100 mm 517	22	41

(1) Other restrictions apply beyond those shown.

Comparison table

	Nearest Equivalent Grade	
BS 7191:1989	**EN10225**	**API 1993**
355D	S355G2+N S355G5+M	
355E	S355G3+N S355G6+M	
355EM	S355G7+N S355G7+M	2H Grade 50 2W Grade 50 2W Grade 50T
355EMZ	S355G8+N S355G8+M	
	S420G1+Q	
	S420G2+Q	
450EM	S460G1+Q	2Y Grade 60
450EMZ	S460G2+Q	

Plate processing

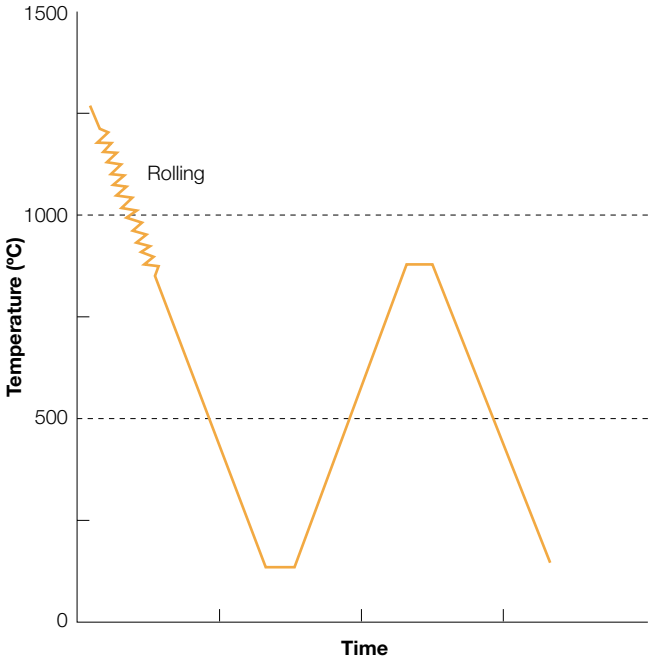
Plates for offshore structural applications are manufactured by Corus with three different delivery conditions:

1. normalised
2. thermomechanically controlled rolled (TMCR)
3. roller quenched & tempered (RQT)

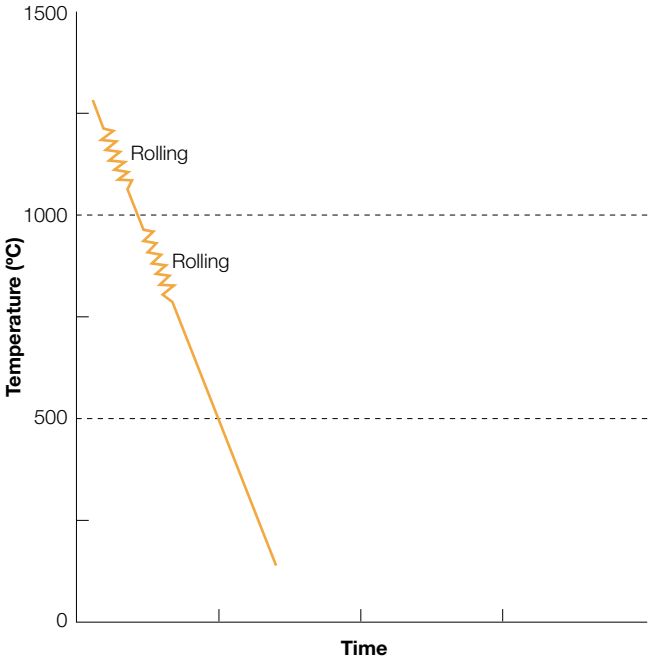
Plates with a nominal yield strength of 355 MPa can be supplied in either the normalised or TMCR condition. Normalised plates are available up to 150 mm thick, and, depending on thickness and/or weight, are rolled either from continuously cast slab or from direct rolled ingots. Plates whose properties are achieved by TMCR are rolled from continuously cast slab and are available up to 65 mm thick. The target chemical compositions for the two types are different as indicated in the subsequent pages of this brochure.

The thermal cycles through which both types of steel plate pass during processing are illustrated below.

Schematic Illustrations of Process Routes



Normalised Plate



TMCR Plate

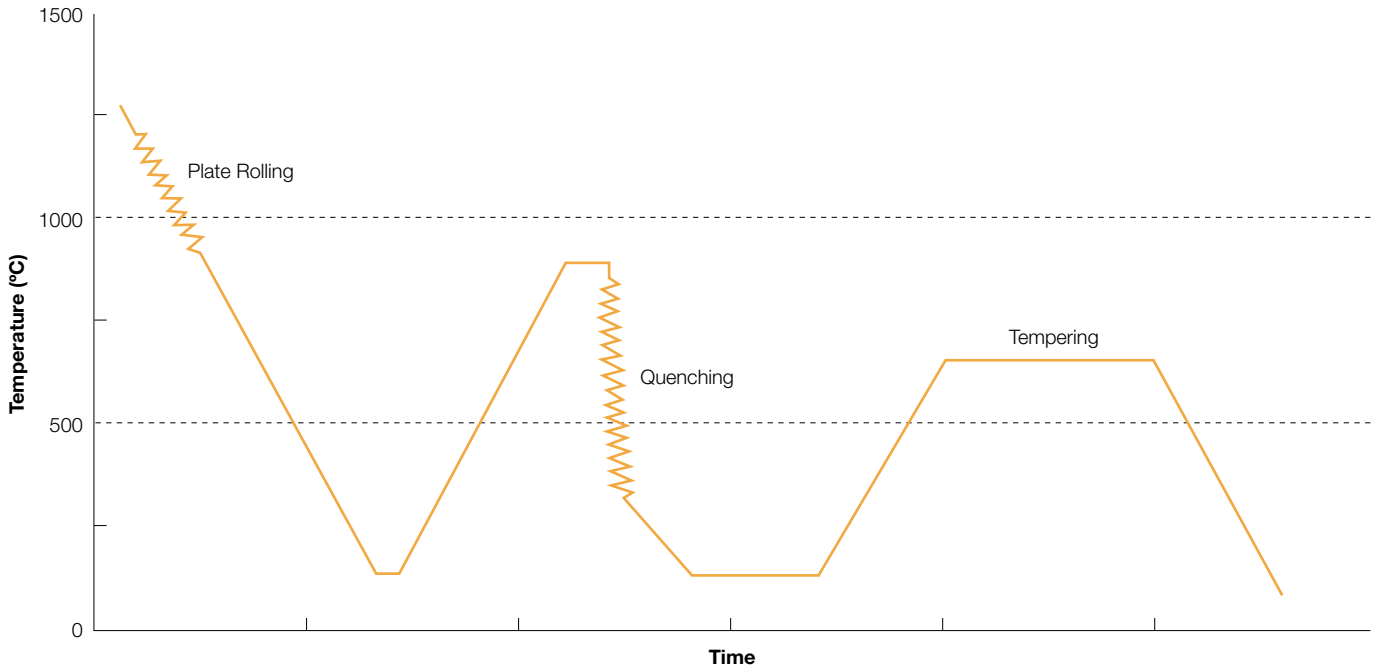
Higher strength plates

Higher strength plates are delivered in the roller quenched and tempered condition. RQT steel plates are produced by heat treating high quality reversing mill plates of the required chemical composition and thickness rolled from continuously cast slabs or direct rolled ingots of low sulphur steel.

The heat treatment of the plates takes place at Corus Clydebridge Works. The plates are heated to a temperature, depending on grade, in the range 880°C to 930°C and then water quenched using a Drever Roller Pressure Quench unit. The plates are quenched at very high cooling rates by large volumes of high pressure water sprayed across the full width of the plate on to both top and bottom surfaces. During the quenching operation the plates are held flat and are in continuous motion, thus ensuring that each part of the plate is cooled at the same rate. The precise rate of cooling during quenching is achieved by controlling the water pressure and the speed of passage of the plate through the unit, allowing consistent properties to be achieved in the final product. The quenching efficiency of this process is extremely high, giving the desired properties with very low levels of microalloying elements and low levels of CEV.

The final levels of strength and toughness are achieved by tempering heat treatments performed in furnaces with uniform temperature distribution and close temperature control. Using this method, plates satisfying grades requiring nominal yields of 420 MPa, 450 MPa and 460 MPa can all be produced from steel slab or ingots of similar target compositions.

Schematic Illustration of RQT Process Routes



Testing

A full range of testing facilities are available within Corus at which the standard testing requirements of each specification are undertaken. Further specialist testing can be undertaken as necessary at one of the Corus Technology Centres.

Non-destructive testing (NDT) facilities are available in-house. When specified, testing is carried out by NDT operators who are certified in accordance with EN473. The NDT facility can be incorporated into the 100% inspection process, an offline activity for checking the product conformity to the standard applied. This inspection service is operated in a dedicated bay by teams of experienced steel inspectors ensuring a high level of service and a quality product.

Certification

Corus certification is in accordance with EN10204. Inspection certificates are normally supplied to Type 3.1.B although at the customer's request other certification can be supplied, e.g. Types 3.1.C, 3.2 and 3.1.A. Certificates are available in English, French and German.

Properties data

The following pages show the typical chemical composition and selected mechanical properties for plates processed using each of the three routes described.

In all three cases the typical chemical composition is given for the full thickness range available. Mechanical properties are presented as histograms showing the distribution of properties achieved in practice when rolling a large number of plates from several different casts of steel. The histograms cover typical thickness ranges used for offshore applications.

Corus will be pleased to discuss your specific requirements and can provide a range of additional data or testing as required. Please use the contact details on the back cover.

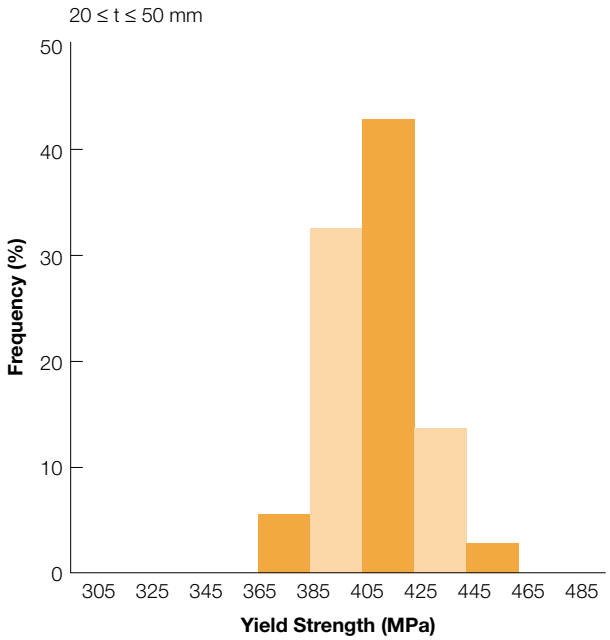
Normalised Grade: BS7191:1989 Grade 355 EM/EMZ

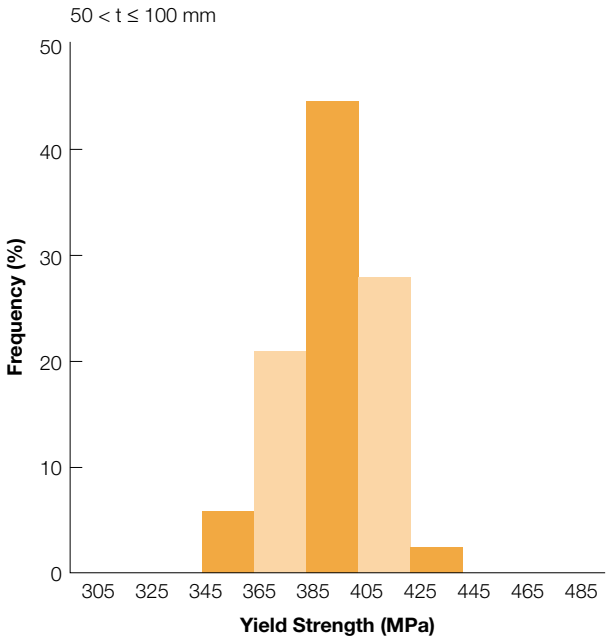
Typical Chemical Analysis (product analysis / wt%)

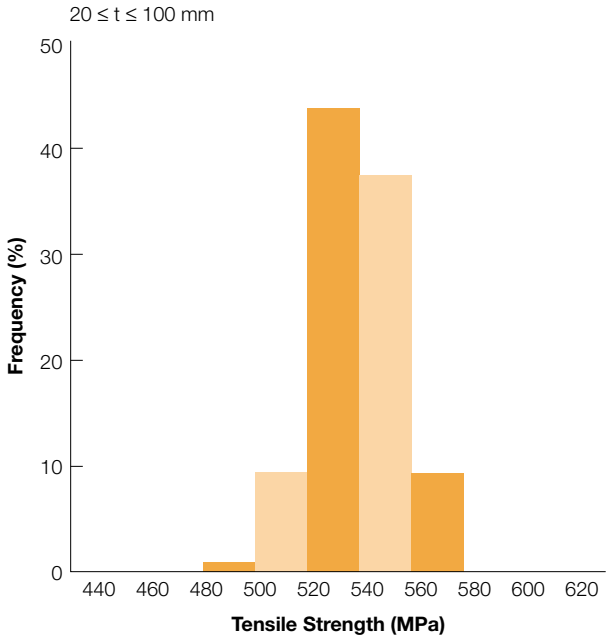
thickness range t / mm	C	Si	Mn	S	P	Cr*	Mo*	Nb	V*	Ti*	Ni	Cu	Al (tot)	N	CEV	Pcm
t ≤ 150	0.11	0.4	1.5	0.004	0.015	0.01	0.005	0.03	0.003	0.005	0.15	0.15	0.03	0.005	0.385	0.21

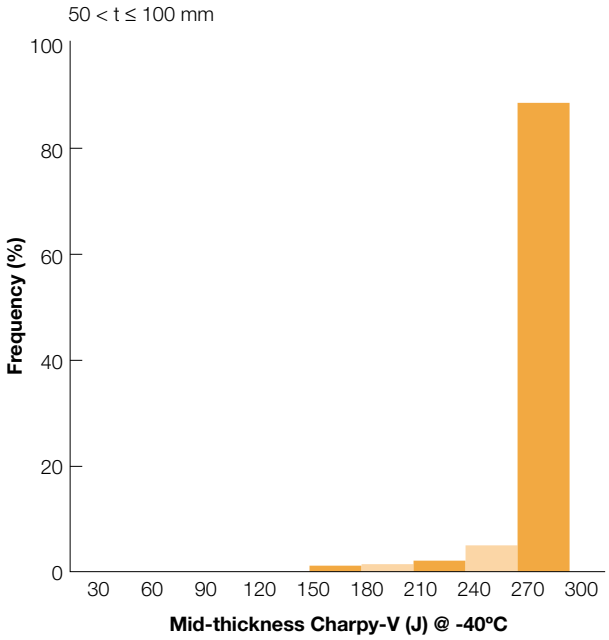
* no deliberate addition

Typical Mechanical Properties.









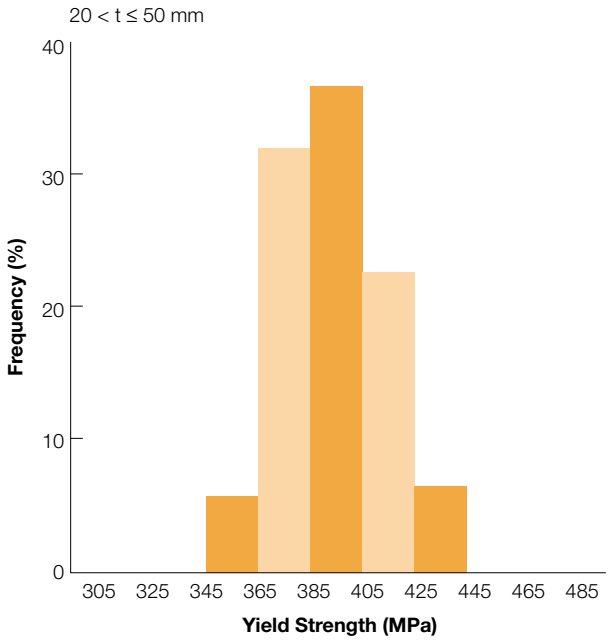
TMCR Grade: BS7191:1989 Grade 355 EM/EMZ

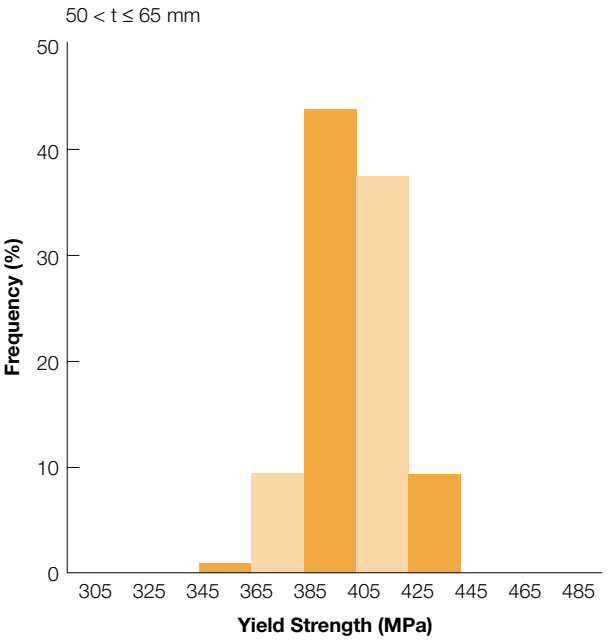
Typical Chemical Analysis (product analysis / wt%)

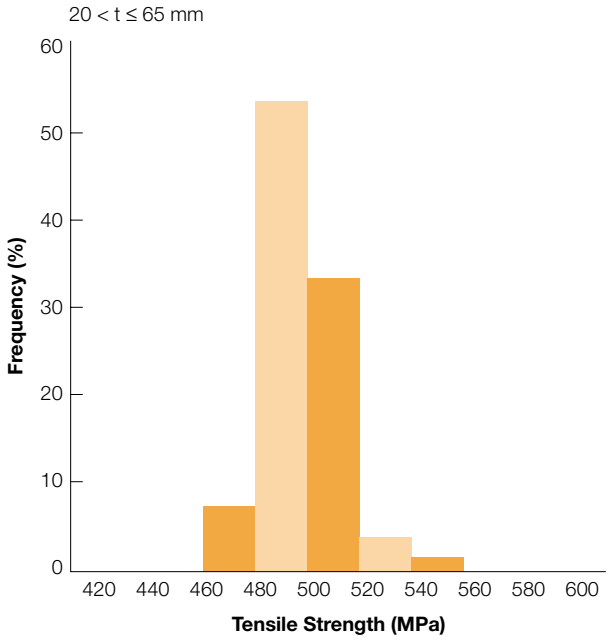
thickness range t / mm	C	Si	Mn	S	P†	Cr	Mo	Nb	V	Ti	Ni	Cu	Al (tot)	N	CEV	Pcm
t ≤ 20	0.075	0.3	1.4	0.003	0.015	0.03*	0.005*	0.023	0.003*	0.005*	0.03*	0.02*	0.035	0.006	0.32	0.16
20 < t ≤ 65	0.07	0.35	1.45	0.003	0.015	0.03*	0.005*	0.02	0.003*	0.008	0.5	0.02*	0.035	0.006	0.35	0.17

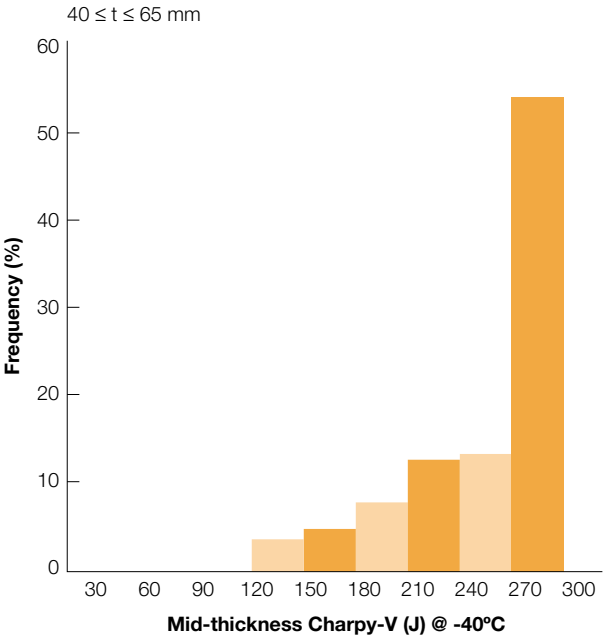
† lower phosphorus levels can be supplied by agreement
* no deliberate addition

Typical Mechanical Properties.









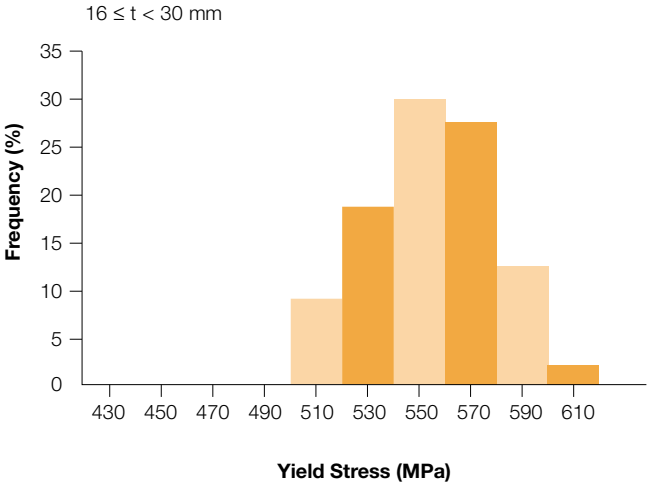
RQT Grade: BS7191:1989 Grade 450 EM/EMZ

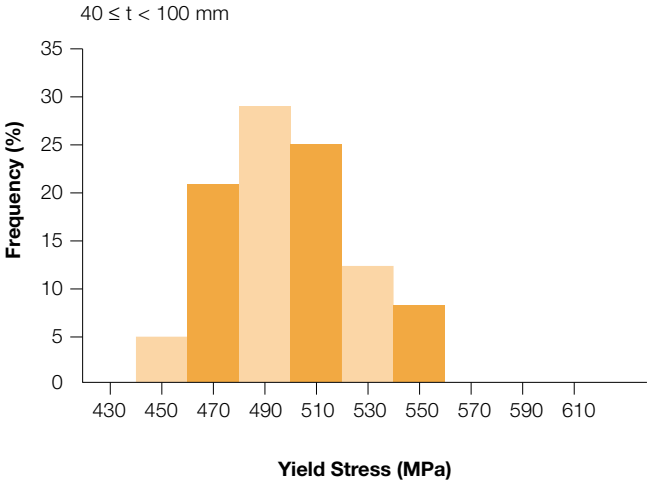
Typical Chemical Analysis (product analysis / wt%)

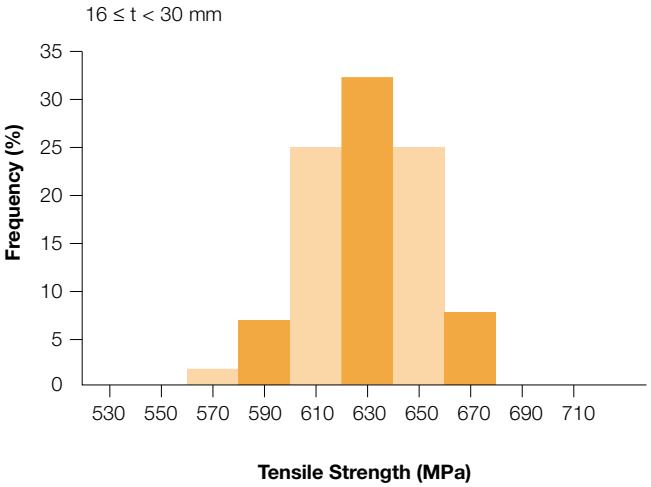
thickness range t / mm	C	Si	Mn	S	P	Cr	Mo	Nb	V	Ti	Ni	Cu	Al (tot)	CEV	Pcm
6 ≤ t < 16	0.12	0.3	1.45	0.003	0.011	0.02*	0.01*	0.003*	0.01*	0.004*	0.02*	0.02*	0.04	0.38	0.2
16 ≤ t < 30	0.08	0.3	1.3	0.003	0.011	0.02*	0.17	0.003*	0.05	0.004*	0.02*	0.02*	0.04	0.34	0.17
30 ≤ t < 40	0.1	0.3	1.3	0.003	0.011	0.02*	0.17	0.003*	0.05	0.004*	0.02*	0.02*	0.03	0.37	0.19
40 ≤ t < 60	0.85	0.3	1.3	0.002	0.011	0.02*	0.17	0.003*	0.05	0.004	0.5	0.02*	0.03	0.38	0.18
60 ≤ t ≤ 100	0.1	0.3	1.3	0.002	0.011	0.02*	0.17	0.003*	0.05	0.004	0.5	0.02*	0.03	0.4	0.2

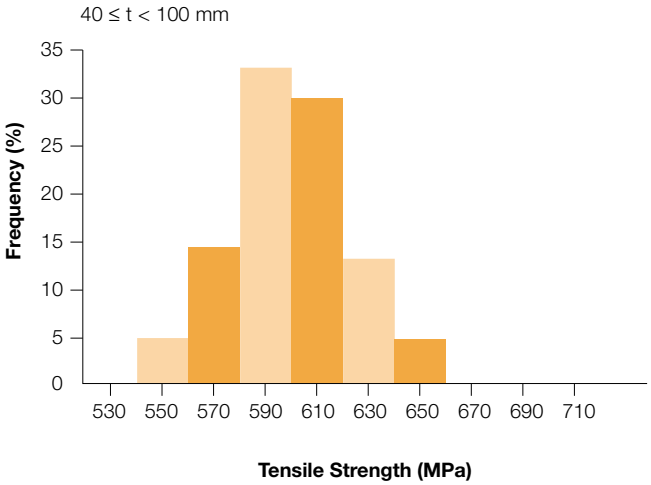
* no deliberate addition

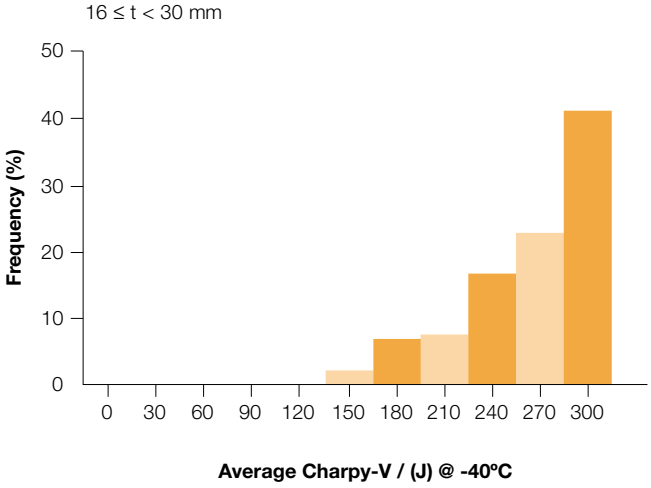
Typical mechanical properties

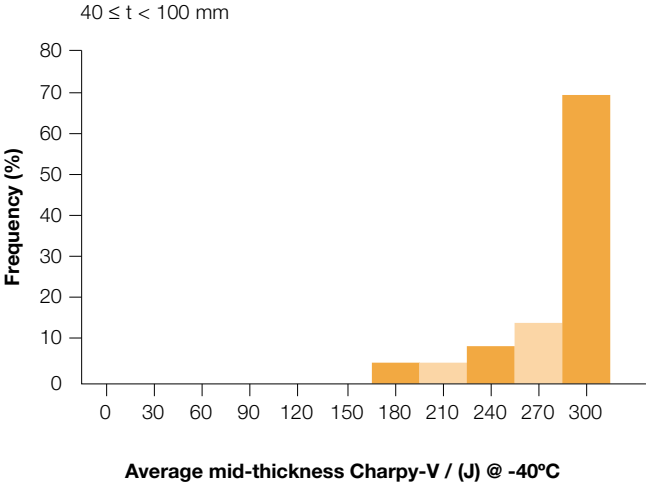












Size availability

These tables show the plate sizes available for each delivery condition.

Maximum plate lengths (m), normalised plates

Typical plate widths (mm)	Plate thickness (mm)																											
	6	8	10	12	12.5	15	20	25	30	35	40	45	50	55	60	63.5	65	70	75	80	85	90	100	110	120	120<t ≤150
1500	12	13.5																								By prior agreement at the enquiry stage
2000	12	13.5																					14.3	13	11.9	
2250	12	13.5																				14.2	12.7	11.6	10.6	
2500	12	13.5																		14.3	13.5	12.7	11.5	10.4	9.5	
2750	12	13.5							15m maximum length (†)									14.9	13.9	13	12.3	11.6	10.4	9.5	8.7	
3050	12	13.5														14.8	14.4	13.4	12.5	11.7	11.1	10.4	9.4	8.5	7.8	
3250*					12.5	12.5									14.7	13.9	13.5	12.6	11.7	11	10.4	9.8	8.8	8	7.3	
3500*					12.5	12.5								14.9	13.6	12.9	12.6	11.7	10.9	10.2	9.6	9.1	8.2	7.4	6.8	
3750*					12.5	12.5								13.9	12.7	12	11.8	10.9	10.2	9.5	9	8.5	7.6	6.9	6.4	
>3750											By prior agreement at the enquiry stage															

Maximum plate lengths (m), TMCR plates

Typical plate widths (mm)	Plate thickness (mm)																
	6	8	10	12	12.5	15	20	25	30	35	40	45	50	55	60	63.5	65
1500	12	13.5															
2000	12	13.5														14.8	14.5
2250	12	13.5													13.9	13.1	12.9
2500	12	13.5												13.7	12.6	11.8	11.6
2750		13.5				15m maximum length (†)							13.7	12.4	11.4	10.8	10.5
3050												13.7	12.3	11.2	10.3	9.7	9.5
3250*					12.5	12.5					14.5	12.9	11.6	10.5	9.6	9.1	8.9
3500*					12.5	12.5					13.5	11.9	10.8	9.8	8.9	8.5	8.3
3750*					12.5	12.5					12.6	11.2	10	9.1	8.4	7.9	7.7
>3750							By prior agreement at the enquiry stage										

Maximum plate lengths (m), RQT plates

Typical plate widths (mm)	Plate thickness (mm)																									
	6	8	10	12	12.5	15	20	25	30	35	40	45	50	55	60	63.5	65	70	75	80	85	90	100	>100
1500	12.0	12.0	12.0	12.0	12.5	12.5				12.5	12.5	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	By prior agreement at the enquiry stage
2000	12.0	12.0	12.0	12.0	12.5	12.5				12.5	12.5	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	11.9	11.3	10.6	9.5	
2250		12.0	12.0	12.0	12.5	12.5	15m maximum length			12.5	12.5	12.0	12.0	12.0	12.0	12.0	12.0	12.0	11.3	10.6	10	9.4	8.5	
2500		12.0	12.0	12.0	12.5	12.5				12.5	12.5	12.0	12.0	12.0	12.0	12.0	11.7	10.9	10.1	9.5	9	8.5	7.6	
2750			12.0	12.0	12.5	12.5				12.5	12.5	12.0	12.0	12.0	11.5	10.9	10.6	9.9	9.2	8.7	8.2	7.7	6.9	
3050			12.0	12.0	12.5	12.5				12.5	12.5	12.0	12.0	11.3	10.4	9.8	9.6	8.9	8.3	7.8	7.4	7	6.3	

* By arrangement

† Plates longer than 15m can be produced by prior agreement at the enquiry stage.

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