Corus Construction & Industrial

Offshore structural products

Steel plate and structural sections

Ahead in the field worldwide

Contents

Expertise and experience - Internationally

Corus is a leading supplier of offshore plate and structural sections. We have delivered over 2,000,000 tonnes to locations throughout the world. From origins in the North Sea we now regularly supply to projects in West Africa, the Gulf of Mexico, the Caspian Sea, the Middle East and Asia.

Corus has much to offer through our unique capabilities in products and support services whether you are a designer, contractor or fabricator. Our product range is both modern and extensive with an accompanying project management service which is specifically designed to support the requirements of those engaged in international offshore oil and gas projects, from the smallest to the very biggest.

The three supporting technical brochures detail Corus' plate range and properties, usage and processing, and structural sections range and their usage.

Corus has developed an enviable reputation for its offshore products and technology over the last quarter of a century. Our early experience was in the North Sea but in recent years we have expanded to supply steel products to most oil and gas bearing regions of the world.

Product range

Corus manufactures a comprehensive range of offshore structural plates and sections to Offshore Specifications BS7191, EN 10225, and API grades as well as a variety of other international and proprietary specifications for applications as shown in the table below. For a comparison of the main specifications please see the separate insert in this pack. The associated technical brochures give more detail of our product capabilities and uses. In addition we have large amounts of detailed technical information which we will be happy to provide and advise upon. See page 9, contact details.

Application	Nominal Yield Strength (min) N/mm²	Typical grades
Module walls and decking	275 355	275D 355D
Module support, cranes and top-sides decking	420 - 460	450EM, 450EMZ Through thickness ductility may be required.
Floating production facilities; hulls, top-sides, turrets, spiders and moorings	235 - 355	Ship grades. A, D, AH36, DH36 355EM, 355EMZ
Jacket legs and module support frames	355 420 - 460	355EM 450EM
Node joints and other areas subject to through thickness stresses	355 420 - 460	355EMZ 450EMZ Through thickness ductility is required.
Steel piles	355 420 - 460	355EM 450EM

The use of FPSO's is an increasing feature of the oil and gas industry and Corus manufactures one of the widest selections of ship plate grades, approved by all the major classification societies such as Lloyds Register, ABS, BV, DNV and many others.

Plate sizes
Gauges from 6 to 120mm
Widths up to 3750mm
Lengths up to 15 metres

Section sizes
127 x 76mm to 914 x 419mm

For detail on the available sizes, please refer to the accompanying technical brochures.

Plate and section processing
Corus offers an extensive range of plate and section fabricating and processing, including can rolling, welding, shotblasting, priming, bevelling, cutting, profiling and drilling. We have experience in fabricating parts for offshore projects and other heavy industrial applications and will be pleased to quote and advise on product use.

Supplying the right grade

Hot on investment

Steelmaking
Corus has invested heavily in steelmaking facilities, particularly in secondary steelmaking equipment.

High quality ores and hot metal desulphurisation enter the primary BOS steelmaking process and are then refined during secondary steelmaking using ladle furnace treatments and vacuum or tank degassing. Deep injection techniques and inclusion modification produce steels appropriate for offshore use.

Very low sulphur
+
Low phosphorous
+
Inclusion modification
+
Excellent cleanness
+
Tight analytical control
=
Strength, toughness and weldability exceeding specification requirements.

The manufacture of quality offshore structural steelwork requires major investment in sophisticated steelmaking facilities and technological resources Corus has made that investment.

Plate and section rolling

Corus has two plate mills and three section mills producing a complementary range of offshore plate and sections. Depending on the specification requirements, thermomechanically controlled rolling is performed, followed by controlled heat treatments including normalising or quenching and tempering.

Corus quench and tempering facilities use sophisticated Roller Quench Technology for assuring highly consistent properties throughout the product.

Quality assurance

Product integrity for offshore structural products is of paramount importance. Corus products, processes and business systems are Quality Assurance approved by Lloyds Register of Quality Assurance to ISO 9001.

This approval covers all aspects of sales, service, design, manufacture and testing. In addition, quality approvals are held from ABS, Lloyds Register of Shipping, DNV, TUV, BV, KRS, MOD, NKK, RINA and also for a number of specific offshore contracts for operators including Shell, BP Amoco, Marathon, TotalFinaElf, Phillips and Chevron.

Delivering vital resources

Total service

Corus recognises that oil and gas projects require ongoing support. This critical requirement is delivered as part of our service package.

Making quality products is only part of the story. Corus recognises that large oil and gas projects require first rate support in the areas of:

- Project management and logistics
- Single point of contact
- Product support - including technical back up and Research and Development

Large and complex projects require the commitment of a company with the skills, experience and resources to deliver. As such a company, we have long been an active partner in major projects be they offshore engineering or construction, operating worldwide.

Project management and logistics

Project management

Corus understands that professional project management is required to successfully deliver large offshore contracts.

We have a dedicated mill-based project management team whose role is to manage the contract from pre-production to post-production back-up and support.

We work in partnership with our clients and customers.

The project manager oversees:

- Pre-order customer liaison covering suggested production plans and, if required, product selection advice and design.
- Implementation of the production and delivery schedule.
- Progress monitoring and prompt resolution of any issues arising.
- Data analyses as requested, of mechanical properties or chemical analysis distributions for instance.

The project manager's aim is to fully understand the customer's requirements and marshall Corus' resources to ensure smooth and successful contract delivery.

Logistics

To facilitate the Project Manager's work, we offer quick start material to get fabrication off to a flying start.

To ensure delivery schedules can be met, we operate a system of capacity reservation which keeps rolling mill time available for the contract.

With you at every step

Single point of contact

Account management

Corus offers account management and all customers can obtain a needs-based multi-product package. Order handling, quotations, logistics and technical information handling are consequently made more efficient.

In addition to the products detailed in these brochures, Corus can supply tubes and hollow sections, engineering grade billets and bars, and wire rod for mooring and tethering rope applications. We have one of the widest product ranges in the business.

Electronic document management

Corus is at the forefront of the metals industry with the use of EDI and internet technology. Standard web browsers allow customers to access order acknowledgements, invoices and test certificates. Advantages include immediate, error free, 24 hour access with this proven system which some Corus customers have incorporated into their own Quality Assurance Systems.

Other Corus innovations available on-line are the sections rolling programme and plate and sections order status visibility.

Product support

Customer technical services

Corus offers professional product support. Corus Customer Technical Services can advise on product use and preparation, welding procedures and many other practical issues.

Research, development and technology (RD&T)

A long term commitment to research and development of our products, processes and processing capabilities is critical. Our corporate RD&T centre is world renowned and a dedicated centre of excellence. We have invested in people and the latest research tools to make first class technical investigation and continual product improvement on our offshore customers' behalf. Detailed additional product information can be provided on request.

A unique service package

We ensure your quotation, order, technical specification and delivery all meet your needs. Our account management team will keep you in touch at every stage of the process.

Contacts

This brochure is an introduction to the extensive product range capabilities and unique service package that Corus provides. However we cannot cover every aspect of our products and services, so please contact us on any matter you wish to discuss.

In the first instance, please contact our Sales Manager, Energy International at:

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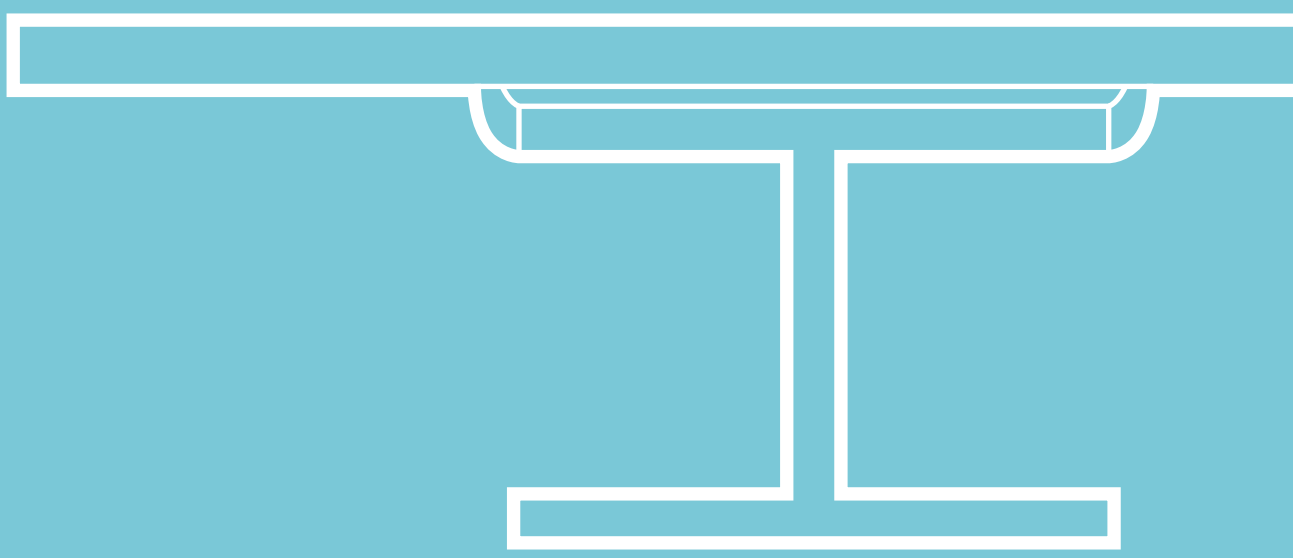
Corus Construction & Industrial

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.

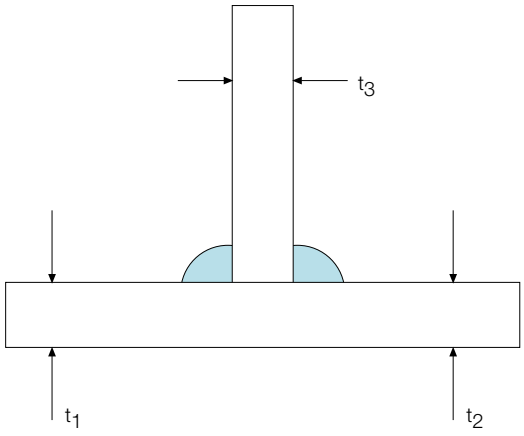
Pre-heat recommendations for the avoidance of HAZ cracking

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.

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

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 $t=t_1=t_2=t_3$.

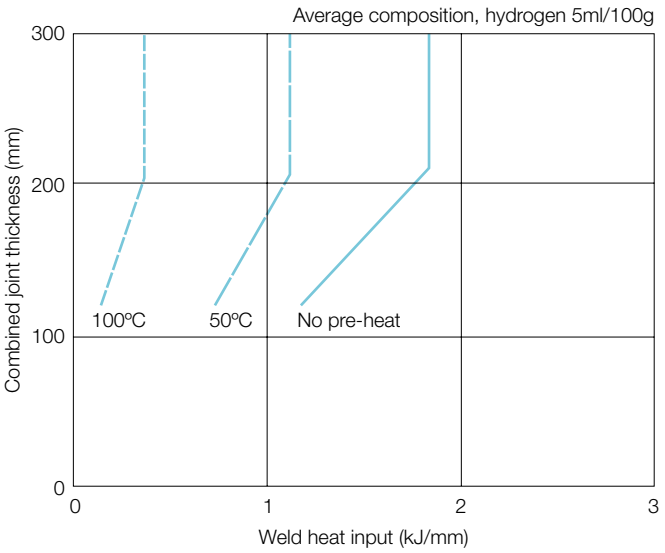


Weld metal cracking

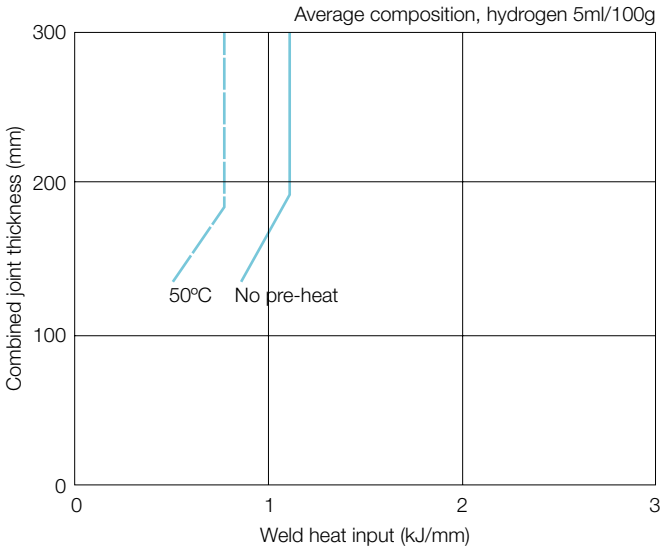
The pre-heat recommendations given above are based solely on the considerations for avoiding HAZ cracking. Due to developments in steel processing it is now possible to achieve strength levels at lower CEV which enables a lower pre-heat to be recommended based on the HAZ. In some instances however, the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

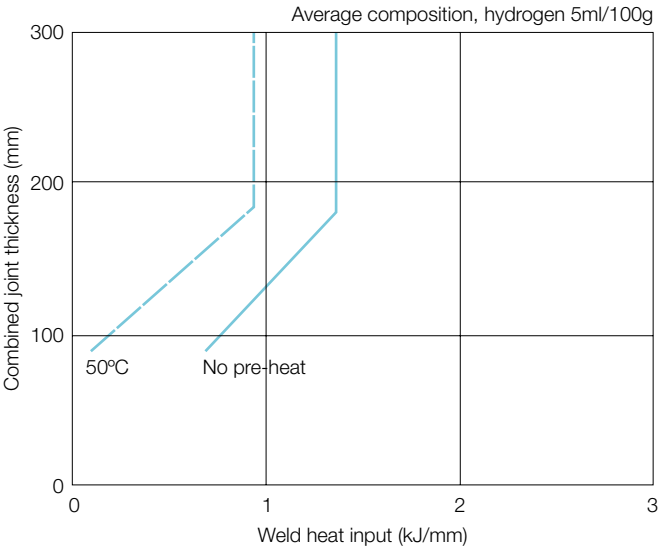
BS7191 grade 355 normalised



BS7191 grade 350/355 TMCR



BS7191 grade 450 quenched and tempered



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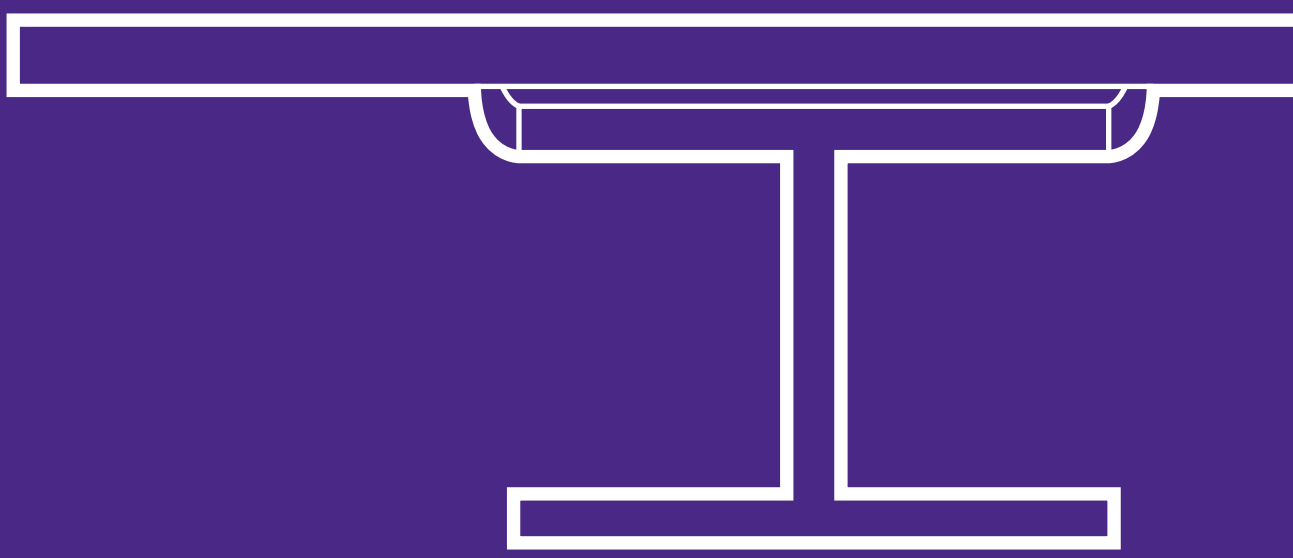
Steel sections for offshore structural applications



Corus is one of the world's leading metals companies with a great breadth of experience supplying steel to the offshore oil and gas industries, providing a full range of products and services for these applications.

This brochure details Corus' range of steel sections for offshore structural applications. Specifications and standards, typical properties achieved and fabrication procedures are described.

Specifications and standards

The following summaries of chemical and mechanical property requirements for typical offshore steel specifications are given as examples of conditions to be achieved.

British Standard BS 7191:1989 Grade 355

Chemical composition (ladle and product analysis / wt%) (1)

Grade	C max	Si	Mn max	P max	S max	Nb	V	Al max	Ti max	Cr max	Ni max	Mo max	Cu max	N max	CEV max
355D (Ladle only)	0.18	0.10/ 0.50	1.50	0.040	0.040	0.003/ 0.10	0.003/ 0.10	-	-	-	-	-	-	-	0.43
355EM	0.18	0.25/ 0.55	1.60	0.025	0.015	0.04 max	0.08 max	0.06(2)	0.02	0.25	0.30	0.08	0.35	0.014	0.43
355EMZ	0.18	0.25/ 0.55	1.60	0.025	0.008	0.04 max	0.08 max	0.06(2)	0.02	0.25	0.30	0.08	0.35	0.014	0.43

(1) Other restrictions apply beyond those shown. (2) Soluble Al to N ratio shall be a minimum of 2:1.

Mechanical properties

Grade	Minimum YS (MPa)			TS (MPa)	Min El ($5.65\sqrt{S_o}$) (%)	Min Ave Charpy V (J)			Z Properties	
	≤16mm	>16 ≤20mm	>20 ≤40mm			Orientation	-20ºC	-40ºC	Min Ave RA (%)	Min TS (MPa)
355D	355	345	-	490 - 640	20	Long	50	-	-	-
355EM	355	345	345	460 - 620	20	Long	-	50	-	-
355EMZ	355	345	345	460 - 620	20	Long	-	50	35(1)	368(1)

(1) Testing is not required for thicknesses below 25mm.

European Standard EN 10225: S355 Grades

Chemical composition (ladle and product analysis / wt%) (1)

Grade	C max	Si max	Mn	P max	S max	Nb max	V max	Al	Ti max	Cr max	Ni max	Mo max	Cu max	N max	CEV max
S355G1	0.20	0.50	0.90/ 1.65	0.035	0.030	0.05	0.12	0.02(2) min	0.030	0.30	0.50	0.10	0.35	0.015	0.43
S355G4 S355G4+M	0.16	0.50	1.60 max	0.035	0.030	0.05	0.10	0.02(2) min	0.050	-	0.30	0.20	0.35	0.015	0.43
S355G11 S355G11+M	0.14	0.55	1.65 max	0.025	0.015	0.04	0.06	0.015/ 0.055(2)	0.025	0.25	0.50	0.08	0.30	0.012	0.43
S355G12 S355G12+M	0.14	0.55	1.65 max	0.020	0.007	0.04	0.06	0.01/ 0.055(2)	0.025	0.25	0.50	0.08	0.30	0.012	0.43

(1) Other restrictions apply beyond those shown.
(2) Total Al to N ratio shall be a minimum of 2:1. When other N binding elements are used, the min Al and Al:N ratio do not apply.

Mechanical Properties

Grade	Minimum YS (MPa)				TS (MPa)	Max YS:TS Ratio	Min El ($5.65\sqrt{S_o}$) (%)	Min Ave Charpy V (J)			Z Properties	
	≤16mm	>16 ≤20mm	>20 ≤40mm	>40 ≤63mm				Orientation	-20ºC	-40ºC	Min Ave RA (%)	Min TS (MPa)
S355G1	355	345	345(1)	-	470 - 630	0.87	22	Long	50	-	-	-
S355G4 S355G4+M	355	345	345(1)	-	450 - 610	0.87	22	Long	50	-	-	-
S355G11 S355G11+M	355	345	345	335	460 - 620	0.87	22	Long	-	50(2)	-	-
S355G12 S355G12+M	355	345	345	335	460 - 620	0.87	22	Long Trans	- -	50(2) 50(3)	35(4)	368(4)

(1) ≤ 25 mm
(2) ≤ 25 mm, test at -20 °C
(3) Transverse impacts optional.
(4) Through thickness tensile testing optional

Comparison Table

BS 7191 Grade	Nearest Equivalent EN 10225 Grade
355D	S355G1, S355G4, S355G4+M
355EM	S355G11, S355G11+M
355EMZ	S355G12, S355G12+M

Competitive lead times

Corus produces structural sections from three rolling mills at Scunthorpe and Teesside in the UK. Regular rolling programmes at each of the mills ensure frequent availability of each section size.

Testing

Many offshore applications require special testing and inspection, and Corus has facilities for large scale testing of mechanical properties in-house. Testing requirements are in accordance with BS7191 and EN10225 at a minimum frequency of one set of tests per 40 tonnes, per cast (unless otherwise stated).

The following mechanical tests constitute one set:
1 tensile test (longitudinal) all grades
1 set of 3 Charpy V-notch impact tests (longitudinal)

The testing frequency increases to 1 set of 3 Charpy V-notch impact tests (longitudinal) per 5 tonnes for BS7191 Grades 355EM and EMZ.

Additional capabilities

For BS7191 Grade 355EMZ (option B.24) and EN10225 Grade G12+M (option 13), through thickness testing at a frequency of 1 per cast is carried out in accordance with EN10164 Quality Class Z35.

Non-destructive testing (NDT) facilities are available in house. When specified, testing is carried out by qualified Corus operators to guarantee internal soundness.

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.

Total quality

Corus products will be delivered in the as-rolled condition, in accordance with EN10021. Surface requirements meet EN10163 parts 1 and 3, and rolling tolerances comply with European Specifications, e.g. EN10034 for beams and columns.

All products have a Corus bar-coded label which shows the customer order and product details. The product can be hard-stamped, colour-coded and stencilled as specified within the BS7191 and EN10225 standard or as agreed with the customer. All products carry the Corus brand, the mill of origin and reference back to cast level.

Accredited Quality Assurance - every rolling mill and steelworks involved in the supply of structural sections operates quality management systems complying with ISO9001. Moreover, every site has been approved by Lloyds Register Quality Assurance (LRQA), a nationally accredited independent third party approval body, as well as many other leading National and International QA organisations.

Certification

Corus certification is in accordance with EN10204. Test certificates are normally supplied to Type 3.1.B. If third party inspection is required, inspectorate-endorsed certificates to Type 3.1.C will be supplied. Certificates are available in English, French and German.

Chemical composition

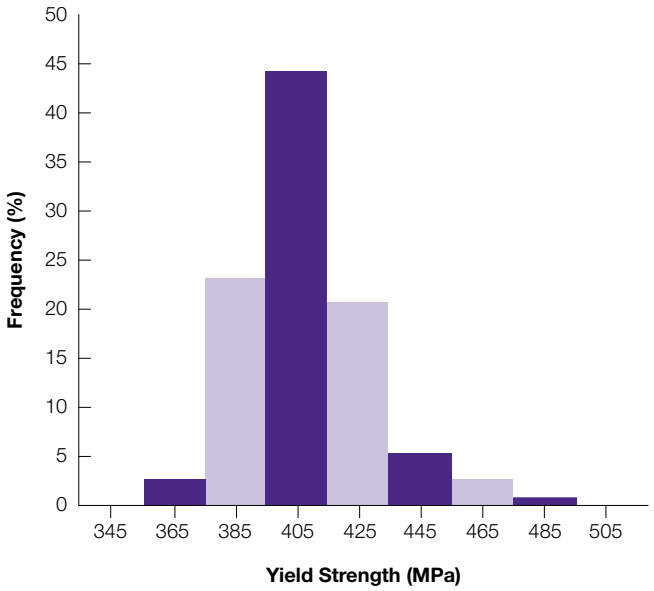
Structural sections are based on a low sulphur, low nitrogen, silicon killed, aluminium fine grained chemistry with a low carbon equivalent value (CEV).

Mechanical properties

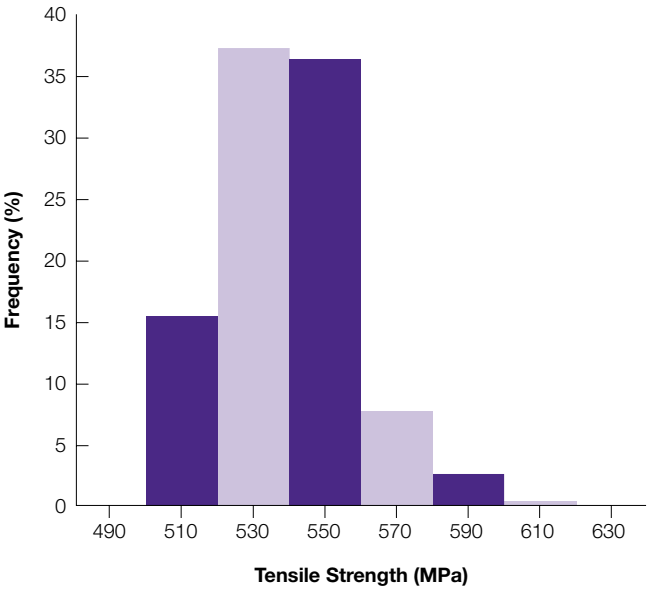
Below are typical examples of mechanical properties measured across the full range of beams and columns produced for offshore structural applications (conforming to BS7191:1989 Grade 355 EMZ).

These histograms illustrate the spread of values that may be expected in the production of large tonnages of beams and columns rolled from a number of casts of steel. Corus' Technical staff will be happy to discuss the benefits shown in this data with reference to your particular requirements. See the back cover for contact details.

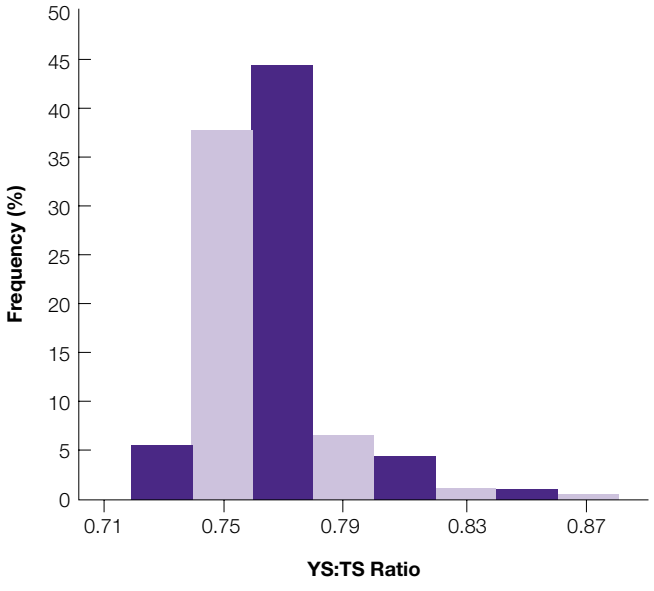
Yield stress



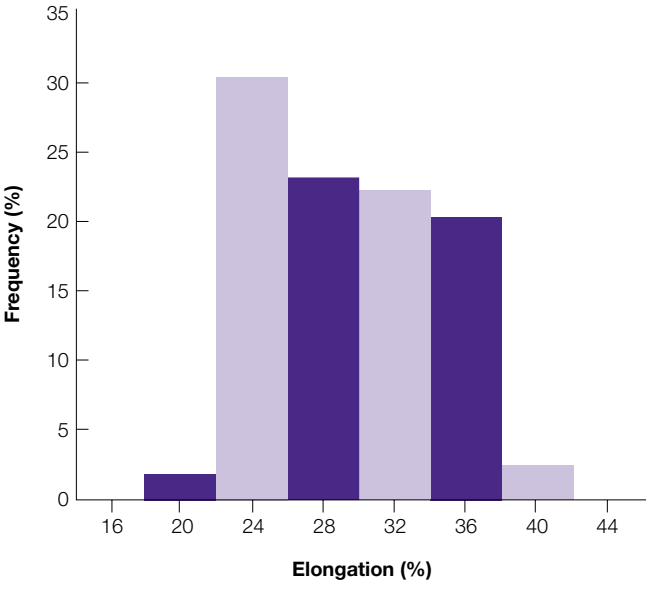
Tensile strength



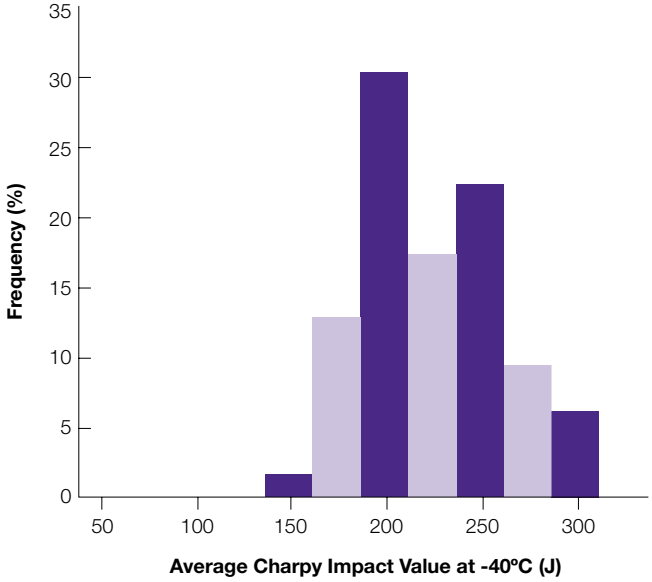
Yield to tensile ratio



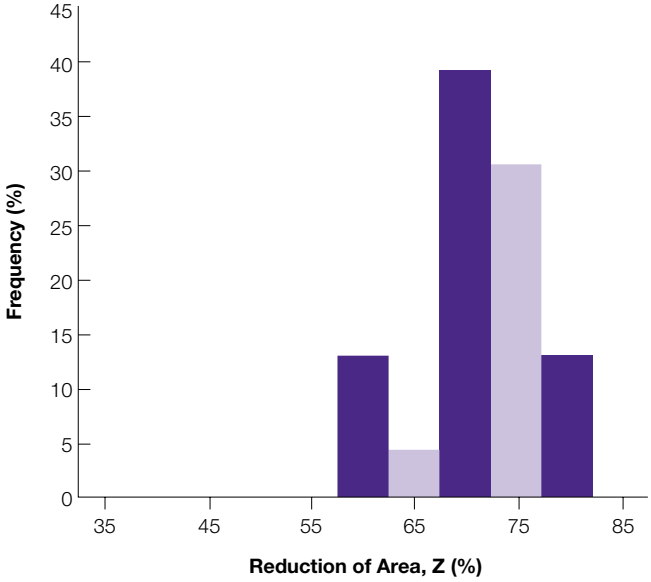
Elongation



Average longitudinal Charpy impact value at -40ºC



Through thickness tensile ductility



High strength steels

Corus would be happy to discuss any requirements for higher strength steels, from the S420 series and above, and any particular requirements for weldability, toughness and mechanical properties. Corus' experience in the manufacture of high strength/high toughness grades is well proven together with an extensive knowledge of the demands of the offshore market. Please use the contact details on the back cover.

Corus can also utilise the facilities of world class R&D teams to further develop steels to meet your requirements.

Size availability

Corus supplies a full range of steel products for offshore applications. Beams, columns, joists, channels and angles are available in all the BS7191 grades and the EN10225 S355 grades, in both metric and imperial denominations. Corus supplies BS, ASTM and Euronorm sizes in flange thicknesses up to 40mm. For sections greater than 40mm, please refer to Corus sales offices.

Corus also provides section sizes, weights and profiles in addition to those listed, including asymmetric beams. Sales office staff will be happy to provide any further information required.

Easy to weld sections

Corus' structural sections have low CEV values and are easy to weld. As with all steel types, the selection of weld procedure must take into account a number of factors linked to the properties of the structural sections. The toughness of the HAZ 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 HAZ hardness and toughness are included in welding standards such as BS EN1011-2:2001. Data on HAZ toughness (based on Charpy - V impact and Crack Tip Opening Displacement laboratory tests) can be obtained from Corus on request. Corus welding metallurgists are available to discuss any queries on specific applications involving weld procedures not covered by BS EN1011 which replaces BS5135:1994. See the back cover for contact details.

British universal beams
127 x 76 mm - 914 x 419 mm

American wide flange sections
W6 x 15 lb/ft - W40 x 327 lb/ft

British universal columns
152 x 152 mm - 356 x 406 mm

Equal angles
90 x 90 mm - 200 x 200 mm

Universal bearing piles
203 x 203 mm - 356 x 368 mm

Unequal angles
100 x 65 mm - 200 x 150mm

Euronorm I beam
IPE 100 mm - 750 mm

Joists
76 x 76 mm - 254 x 203 mm

Euronorm H beam
HE 100 mm - 1000 mm

Parallel flange channels
100 x 50 mm - 430 x 100 mm

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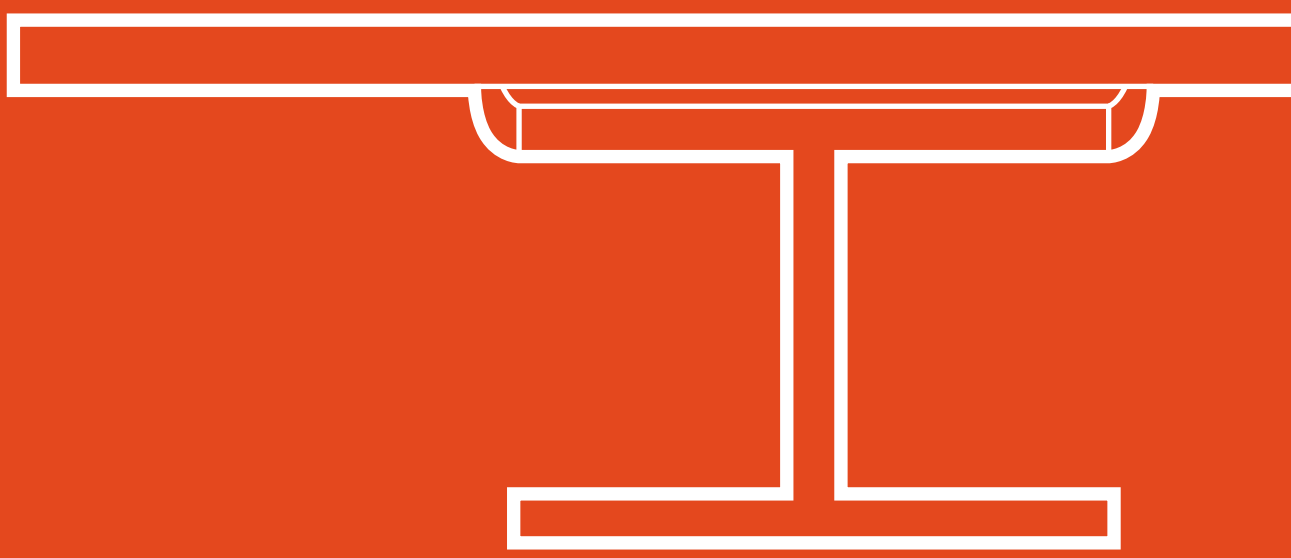
English language version

EC08/01

Corus Construction & Industrial

Offshore structural products

Comparison of common offshore specifications



Corus manufactures high quality offshore steel plates and sections satisfying a range of national, international and individual customer specifications.

Comparison of Common Offshore Standards

EN 10225 designations		Nearest BS 7191:1989 designations		Former NORSOK M-120 designations*		Nearest API 1993 designations**
Plates	**Sections**	**Plates**	**Sections**	**Plates**	**Sections**	**Plates**
	S355G1		355D			
S355G2+N	S355G1+N	355D	355D		Y03 S355N1	
S355G5+M		355D				
	S355G4		355D			
S355G3+N		355E				
S355G6+M	S355G4+M	355E	355D			
	S355G11		355EM			
S355G7+N	S355G11+N	355EM	355EM		Y26 S355N3	2H Grade 50
S355G7+M	S355G11+M	355EM	355EM		Y26 S355M3	2W Grade 50 2W Grade 50T
S355G12		355EMZ				
S355G8+N	S355G12+N	355EMZ	355EMZ		Y21 S355N3z	2H Grade 50
S355G8+M	S355G12+M	355EMZ	355EMZ		Y21 S355M3z	2W Grade 50 2W Grade 50T
S355G9+N				Y25 S355N4		
S355G9+M				Y25 S355M4		
S355G10+N				Y20 S355N4z		
S355G10+M				Y20 S355M4z		
	S420G3					
S420G1+Q				Y35 S420Q3		2Y Grade 60
S420G1+M	S420G3+M			Y35 S420M3	Y36 S420M3	2W Grade 60
	S420G4					
S420G2+Q				Y30 S420Q3z		2Y Grade 60
S420G2+M	S420G4+M			Y30 S420M3z	Y31 S420M3z	2W Grade 60
	S460G3					
S460G1+Q		450EM		Y45 S460Q3		2Y Grade 60
S460G1+M	S460G3+M	450EM		Y45 S460M3	Y46 S460M3	2W Grade 60
	S460G4					
S460G2+Q		450EMZ		Y40 S460Q3z		2Y Grade 60
S460G2+M	S460G4+M	450EMZ		Y40 S460M3z	Y41 S460M3z	2W Grade 60

*The current NORSOK standard M-120 is aligned with EN10225.
** There is no directly comparable API specification for sections, however Corus will advise on appropriate alternatives.

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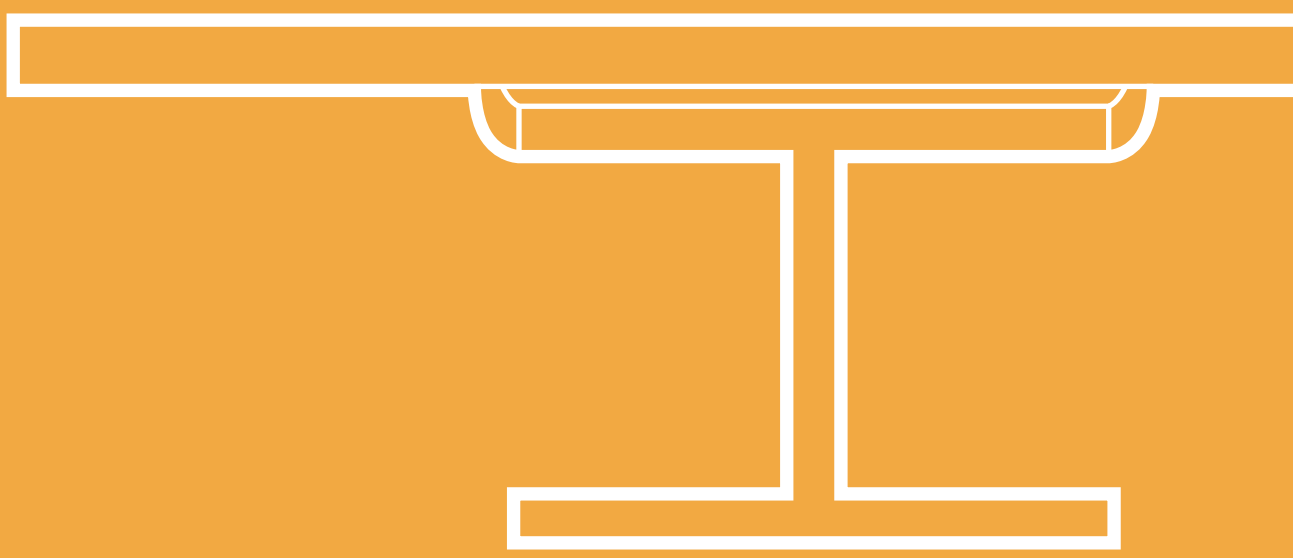
Corus Construction & Industrial

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

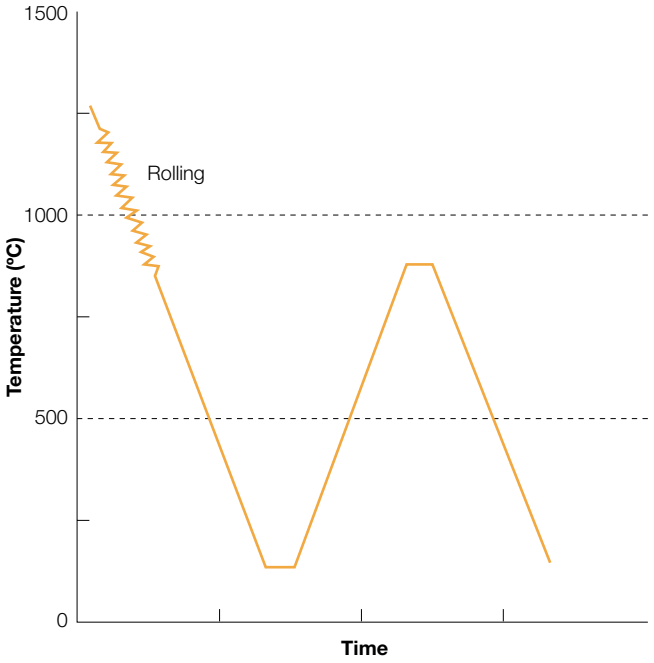
Plates for offshore structural applications are manufactured by Corus with three different delivery conditions:

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

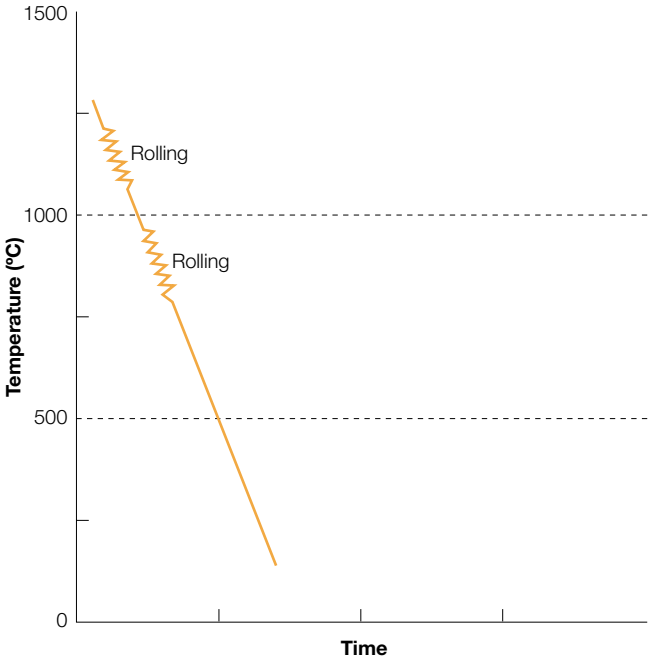
Plates with a nominal yield strength of 355 MPa can be supplied in either the normalised or TMCR condition. Normalised plates are available up to 150 mm thick, and, depending on thickness and/or weight, are rolled either from continuously cast slab or from direct rolled ingots. Plates whose properties 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

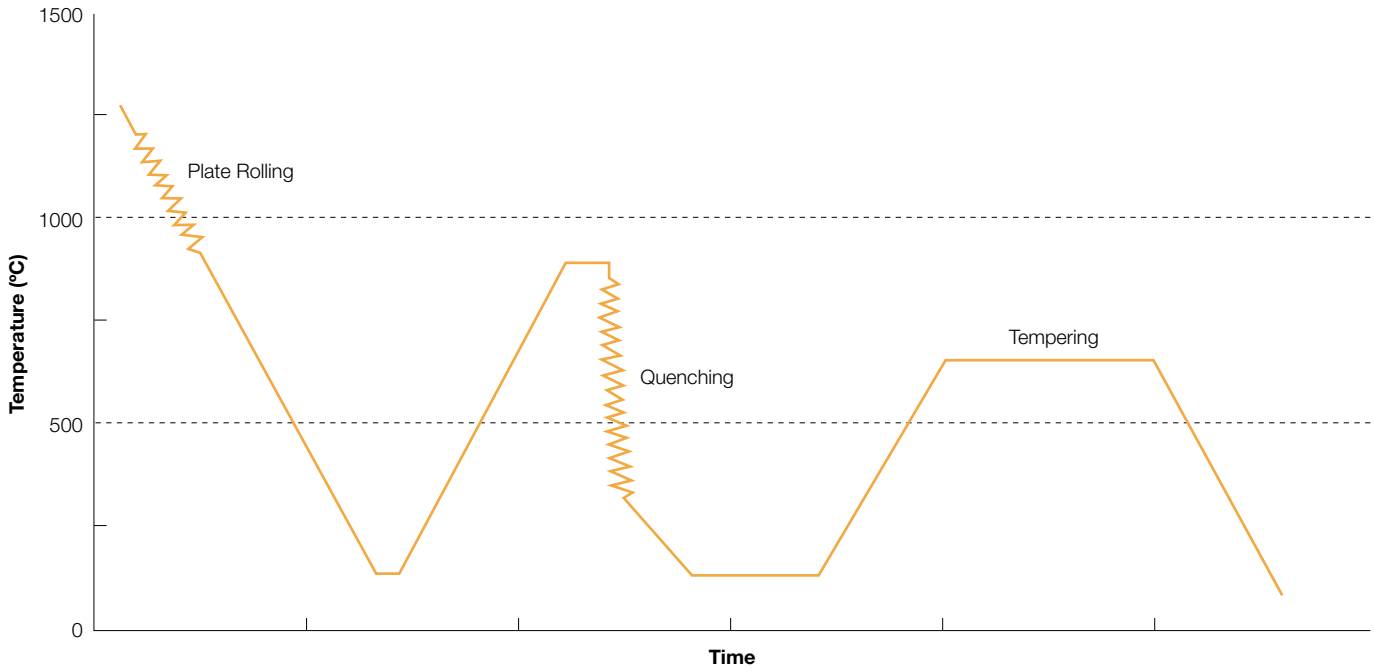
Higher strength plates

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.

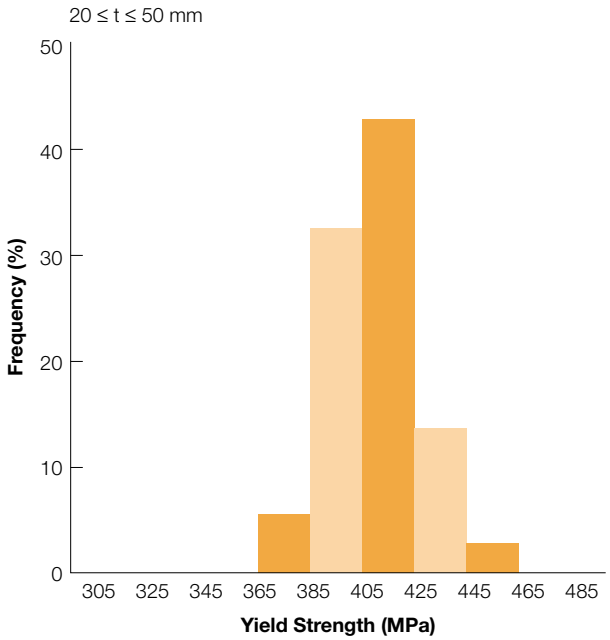
Normalised Grade: BS7191:1989 Grade 355 EM/EMZ

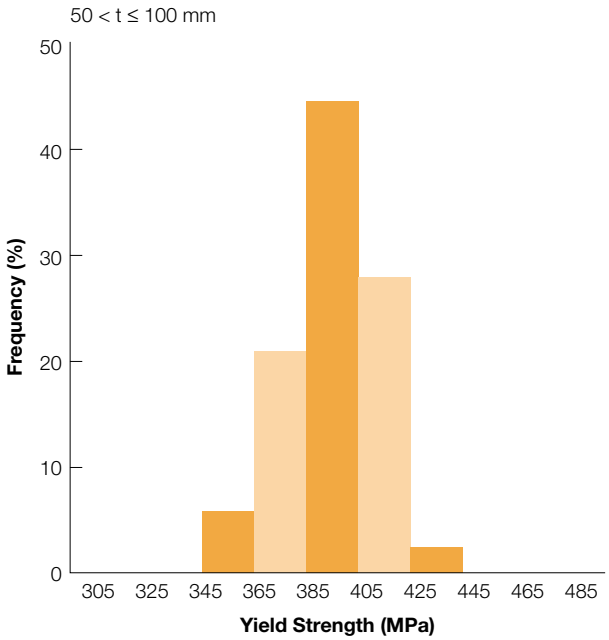
Typical Chemical Analysis (product analysis / wt%)

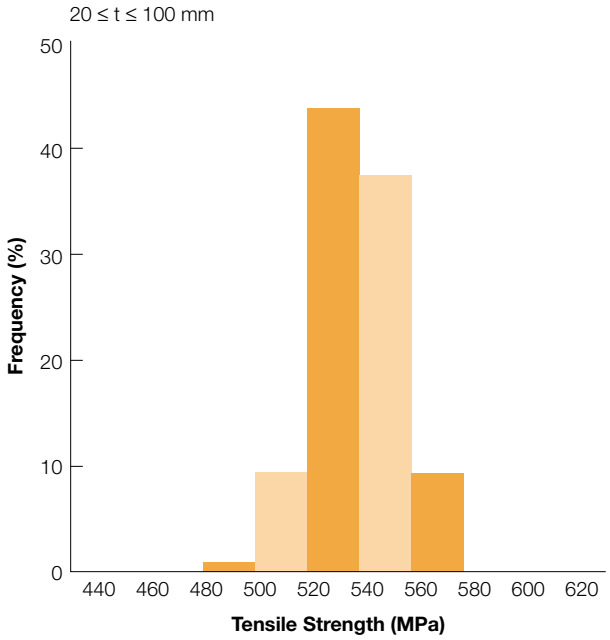
thickness range t / mm	C	Si	Mn	S	P	Cr*	Mo*	Nb	V*	Ti*	Ni	Cu	Al (tot)	N	CEV	Pcm
t ≤ 150	0.11	0.4	1.5	0.004	0.015	0.01	0.005	0.03	0.003	0.005	0.15	0.15	0.03	0.005	0.385	0.21

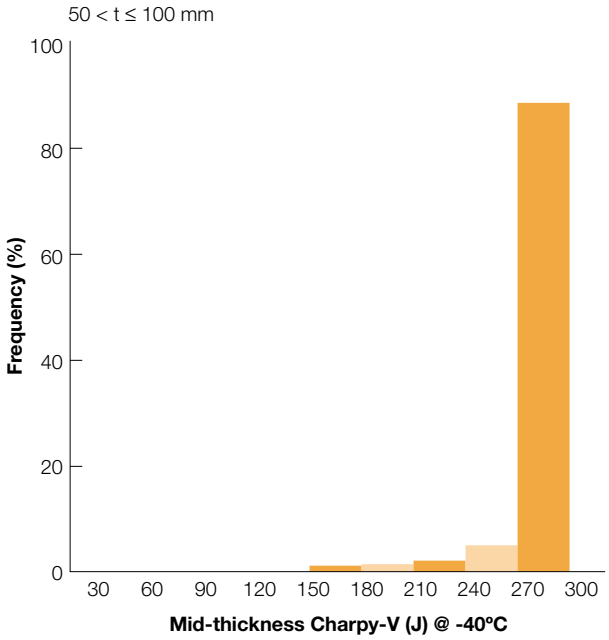
* no deliberate addition

Typical Mechanical Properties.









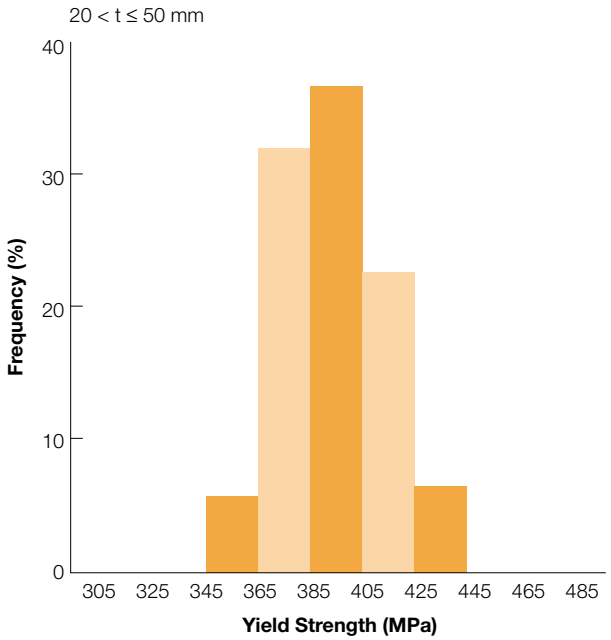
TMCR Grade: BS7191:1989 Grade 355 EM/EMZ

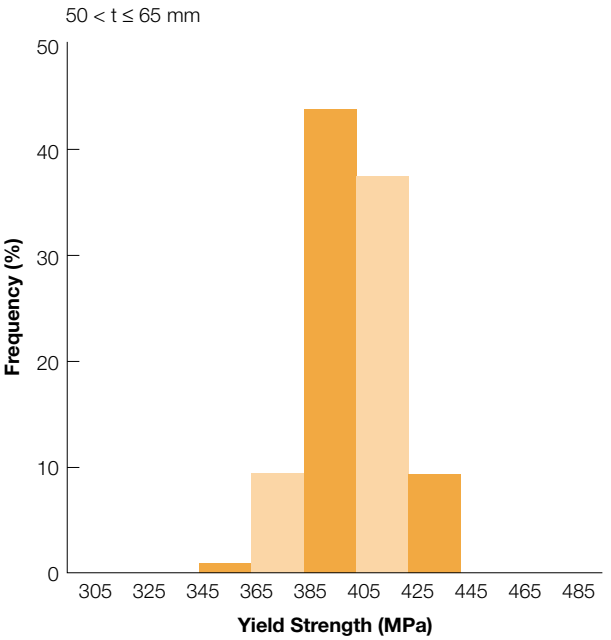
Typical Chemical Analysis (product analysis / wt%)

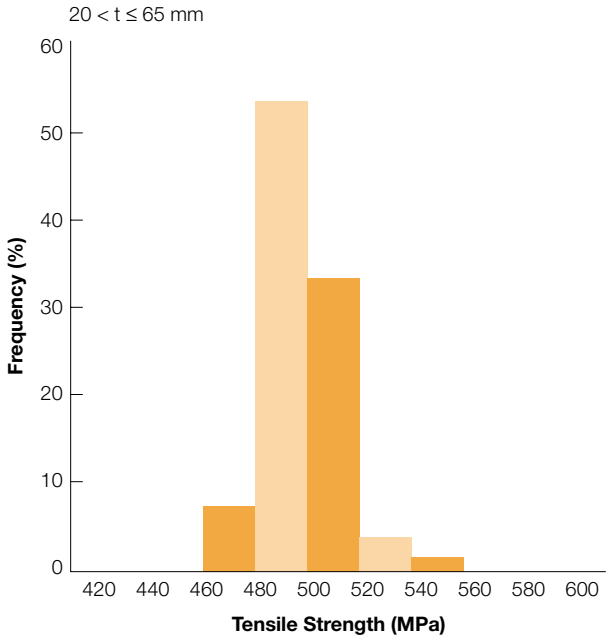
thickness range t / mm	C	Si	Mn	S	P†	Cr	Mo	Nb	V	Ti	Ni	Cu	Al (tot)	N	CEV	Pcm
t ≤ 20	0.075	0.3	1.4	0.003	0.015	0.03*	0.005*	0.023	0.003*	0.005*	0.03*	0.02*	0.035	0.006	0.32	0.16
20 < t ≤ 65	0.07	0.35	1.45	0.003	0.015	0.03*	0.005*	0.02	0.003*	0.008	0.5	0.02*	0.035	0.006	0.35	0.17

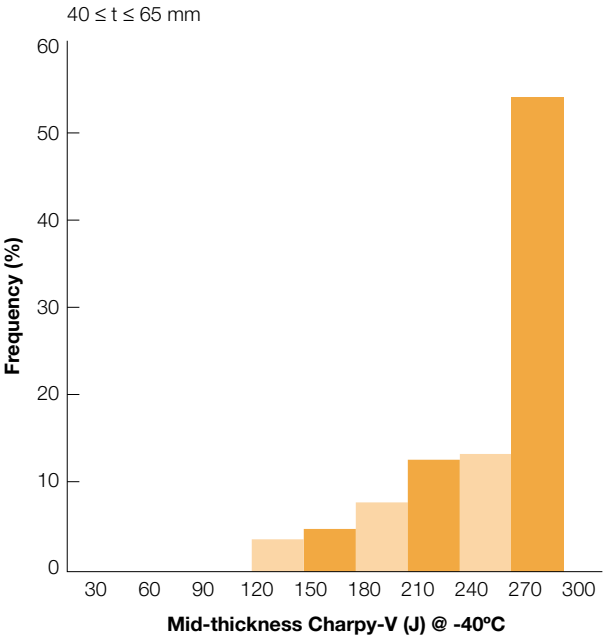
† lower phosphorus levels can be supplied by agreement
* no deliberate addition

Typical Mechanical Properties.









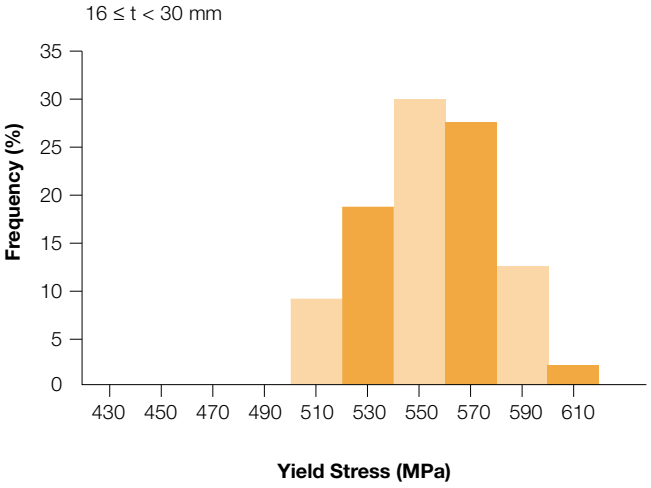
RQT Grade: BS7191:1989 Grade 450 EM/EMZ

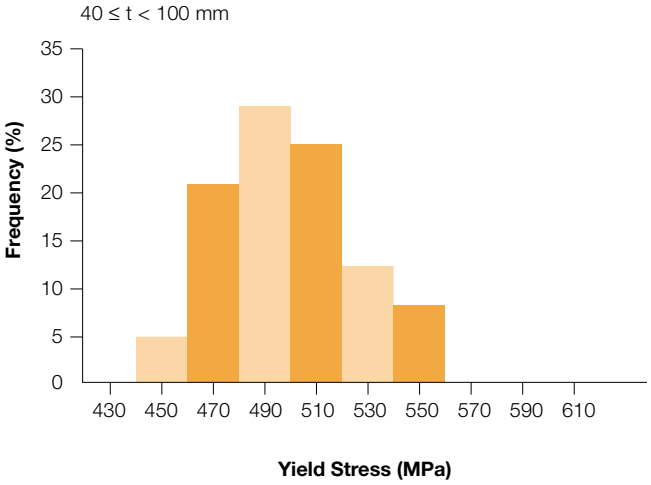
Typical Chemical Analysis (product analysis / wt%)

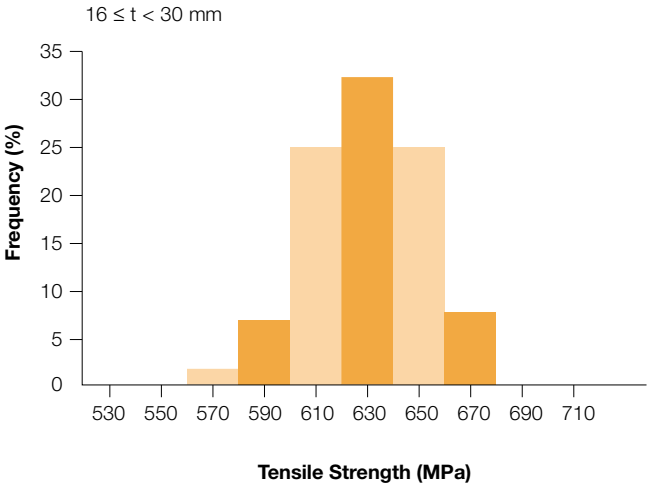
thickness range t / mm	C	Si	Mn	S	P	Cr	Mo	Nb	V	Ti	Ni	Cu	Al (tot)	CEV	Pcm
6 ≤ t < 16	0.12	0.3	1.45	0.003	0.011	0.02*	0.01*	0.003*	0.01*	0.004*	0.02*	0.02*	0.04	0.38	0.2
16 ≤ t < 30	0.08	0.3	1.3	0.003	0.011	0.02*	0.17	0.003*	0.05	0.004*	0.02*	0.02*	0.04	0.34	0.17
30 ≤ t < 40	0.1	0.3	1.3	0.003	0.011	0.02*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

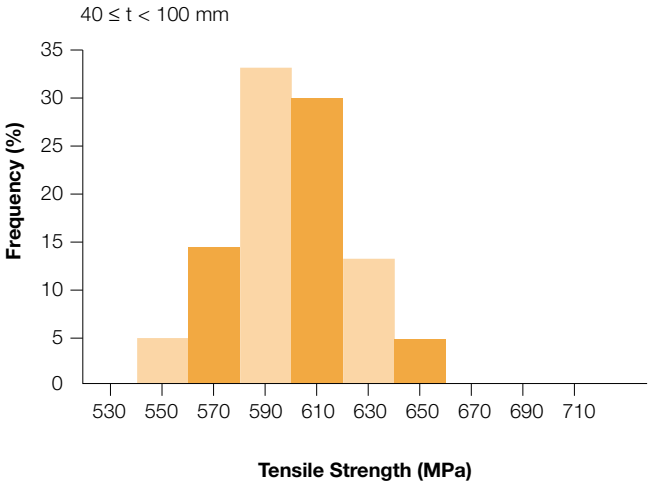
* no deliberate addition

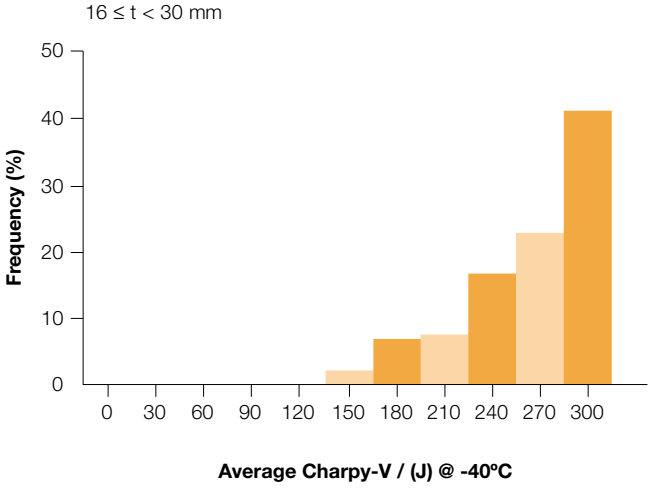
Typical mechanical properties

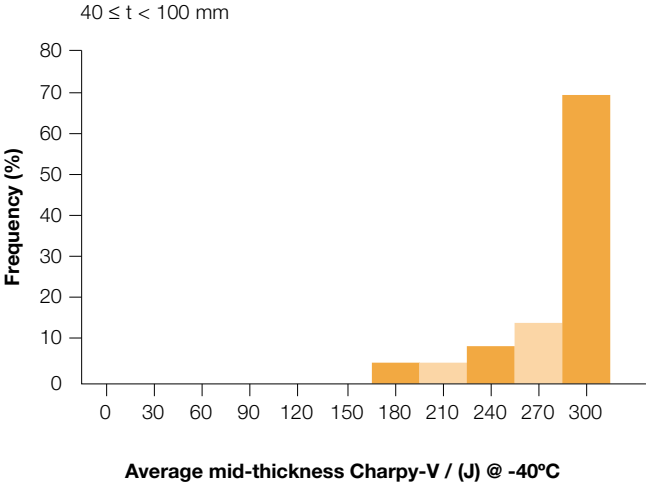












Size availability

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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