
British Standard Specification for
**Weldable structural steels for
fixed offshore structures**

Aciers de construction soudables pour structures fixes en mer — Spécification

Schweißbare Baustähle für stationäre Bauten im küstennahen Bereich

Foreword

This British Standard has been prepared under the direction of the Iron and Steel Standards Policy Committee and specifies weldable structural steels for use in construction and in maintenance work for offshore structures.

The standard is adapted from BS 4360. It has been drafted in the form of a procurement specification and is intended to be used by the purchaser and others acting on his behalf to procure materials for offshore structures designed to operate in the European Sector. It specifies a more limited range of steel forms and grades than BS 4360 and provides for enhanced properties in some grades to reflect the needs of the European offshore industry. It also incorporates a number of options which the purchaser may invoke to meet demanding requirements in particular applications. The format and editorial style of BS 4360 has been utilized to the maximum extent possible.

The new grade designations, which are given in appendix H of BS 4360 : 1986, and which will be adopted in the next full revision of that standard have been used but with an amended form of sub-grade suffix.

Assessed capability. Users of this British Standard are advised to consider the desirability of assessment and registration of a supplier's quality systems against the appropriate Part of BS 5750 by a third party certification body.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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Section one. General

1 Scope

This British Standard specifies requirements for weldable structural steels to be used in the fabrication of fixed offshore structures in the form of plates, up to and including 150 mm thick, sections complying with BS 4848 : Parts 2, 4 and 5 and BS 4 : Part 1, and seamless tubulars up to and including 40 mm thick.

In the case of welded tubulars this standard covers only the requirements for parent material.

Minimum yield strengths up to 450 N/mm² are specified together with low-temperature impact properties at temperatures down to -40 °C.

The standard is applicable to offshore structures designed to operate in the European offshore sector but not to steel supplied for the fabrication of subsea pipelines, risers, process equipment, process piping, and other utilities. It is primarily applicable to the North Sea Sector, but may also be applicable in other areas provided that due consideration is given to local conditions, e.g. temperature.

This standard applies to material supplied ex-mill (see 12.1) or from merchant's stock (see 12.2).

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard the definitions given in BS 6562 : Part 2 apply, together with the following.

2.1 parent product. The product rolled from one piece of steel.

2.2 manufacturer. The manufacturer of the steel products.

2.3 supplier. The manufacturer of material supplied ex-mill, either/or the merchant for material supplied from a merchant's stock (see clause 1).

2.4 purchaser. The purchaser or his representative.

2.5 controlled rolling. A generic term for rolling procedures in which the temperatures and deformation during rolling are controlled to achieve desirable material properties.

2.6 thermo-mechanical controlled rolling (TMCR). A rolling procedure in which significant deformation takes place at temperatures below the normalizing range permitting little, if any, recrystallization of austenite and conferring beneficial properties on the material. The properties conferred by TMCR cannot be reproduced by subsequent normalizing or other heat treatments.

2.7 concast. Material produced by a continuous casting process route.

3 General

3.1 Grade designations

The new grade designations given in appendix H of BS 4360 : 1986 have been used but with amended sub-grade suffixes as follows.

Grade 275	Previous grade 43
Grade 355	Previous grade 50
Grade 450	Previous grade 55
Suffix D	Charpy V-notch test at -20 °C (as BS 4360)
Suffix E	Charpy V-notch test at -40 °C (as BS 4360)
Supplementary suffix M	Substantial modification to the nominally equivalent BS 4360 grade
Supplementary suffix Z	With specified through-thickness properties

This standard includes the following grades.

Grades with few changes from BS 4360	275D, 275E, 355D, 355E (minor changes to CEV and impact requirements only)
Grade as above but with through-thickness properties	275EZ
Grades substantially modified from BS 4360	355EM, 355EMZ, 450EM, 450EMZ

Appendix A gives a comparison between grades in this standard and those in appendix H of BS 4360 : 1986.

NOTE. Clauses in this standard are applicable to all grades except where specifically marked to indicate that they are applicable only to the substantially modified M or MZ grades.

3.2 Steel products

The steel products shall comply with the general requirements of this standard and with the specific requirements applicable to the grade concerned. Where any of the options given in appendix B are called up at the time of the enquiry and order, the steel products shall, in addition, comply with the requirements of these options.

4 Information to be supplied by the purchaser

4.1 General

The following information shall be supplied by the purchaser at the time of enquiry and order.

- Details of the product form, dimensions and quantity.
- The grade of steel (see tables 8 to 13).
- Whether use is for primary or secondary application.

4.2 Options

A number of options are specified in appendix B. In the event that the purchaser does not indicate his wish to implement any of these options and specify his requirements at the time of the enquiry and order, the supplier shall supply in accordance with the basic specification.

See also option B.1.

5 Steelmaking and manufacturing process

5.1 Process

5.1.1 *Grades 275D, 275E, 355D and 355E.* The steel shall be made by any process except the Bessemer process.

5.1.2 *Modified grades 355EM and 450EM.* The steel shall be made by the basic oxygen or basic electric arc furnace process. All steel shall be fully killed and made to fine grain practice.

5.1.3 *Z grades 275EZ, 355EMZ and 450EMZ.* The steel shall be made by a low sulphur and phosphorus refining process in a basic oxygen or basic electric arc furnace. All steels shall be fully killed and made to a fine grain practice. The steel for these grades shall be vacuum degassed or ladle refined.

5.2 Rimming steel

Rimming steel shall not be supplied.

5.3 Limits and segregation control for concast modified grades

5.3.1 Provided that the resultant products comply with all the relevant requirements of this standard, the maximum thickness limit for the use of the continuous casting process shall be at the manufacturer's discretion.

See also option B.2.

5.3.2 The minimum rolling reduction ratio of concast material for plate shall be 4:1.

See also option B.3.

5.3.3 Slab produced by the continuous casting route shall be examined for centreline segregation. The frequency of testing shall be once per strand per four casts.

NOTE. No acceptance levels are specified and the manufacturer should agree with the purchaser, at the time of the enquiry and order, the position of testing and the acceptance values for sulphur printing, macro-etching or alternative methods of checking segregation.

5.4 Plate forming procedures for modified grades

Plate forming procedures shall not be supplied.

See also options B.4 and B.5.

6 Supply condition (see also option B.6)

6.1 Plates of grades 275 and 355 shall be supplied in the normalized condition.

6.2 Plates of grade 450 shall be roller quenched and tempered.

See also option B.7.

6.3 Sections of grades 275 and 355 over 25 mm thick shall be normalized.

6.4 Seamless tubulars over 12.7 mm wall thickness shall be supplied in the normalized condition except for grade 450 which shall be supplied quenched and tempered.

7 Chemical composition and mechanical properties (see also option B.8)

7.1 Ladle analysis

7.1.1 *General.* The chemical composition of the steel shall be determined by ladle analysis and shall be as given in tables 8, 10 and 12.

The manufacturer shall supply details of the ladle analysis to the purchaser and this shall be an average based on at least three samples per cast.

7.1.2 *Residual element control for modified grades 355EM, 355EMZ, 450EM, 450EMZ.* Boron (B) shall not be intentionally added to the steel nor shall vanadium (V) for plate of grades other than 450EM and 450EMZ. Elements other than those listed in tables 8, 10 and 12 shall not be intentionally added. Calcium treatment shall not be used without the permission of the purchaser, except where required for the purposes of desulphurization (see calcium limits given in tables 8, 10 and 12).

7.2 Product analysis

The product analysis shall comply with the limits given in tables 8, 10 and 12 and, in the case of modified grades, shall also be within the ranges proposed by the manufacturer (see 7.3).

See also option B.8.

Product analysis shall be determined twice per cast or once per 40 t, or part thereof, whichever is more stringent. The product analysis shall be determined on the test sample used for the verification of the mechanical properties (see section three).

In the event of dispute, compliance with this standard shall be decided on the basis of an independent analysis using the methods described in BS 6200 : Part 3 or BSI Handbook No. 19, whichever is applicable.

7.3 Carbon equivalent value (CEV)

The steel shall have a maximum CEV, as given in table 1, based on product analysis and calculated using the following equation:

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

7.4 Mechanical properties

Mechanical properties shall be as given in table 9 for plates, table 11 for sections and table 13 for seamless tubulars.

NOTE. Individual manufacturers are able to supply steels with specified minimum yield strengths slightly above those specified in tables 9, 11 and 13. Advantage may be taken of such higher values if the manufacturer can supply sufficient property data. If this approach is adopted, all property values may be agreed separately with the purchaser.

8 Weldability data for modified grades

NOTE 1. Weldability data are only required for plates exceeding 40 mm in thickness and for rolled sections and seamless tubulars over 25 mm in thickness.

At the time of the enquiry/order the manufacturer shall have available data on the weldability of his material.

Any previously obtained data which the manufacturer proposes to submit shall have been verified by a competent third party, acceptable to the purchaser and who witnessed the tests. All previously obtained data presented shall bear the manufacturer's stamp or seal.

NOTE 2. These data refer only to the weldability of the material being supplied and are intended for use in development and preparation of fabrication procedures. If these data are unacceptable to the purchaser he should consider option B.9.

9 Quality of finished steel

9.1 Plates

9.1.1 Surface condition. All surfaces shall be 100 % visually inspected. The surface condition shall comply with BS 6512 except as otherwise specified in this clause. Plates shall be presented for inspection such that the steel surface can be readily examined.

Weld repair by the manufacturer or supplier shall not be carried out.

The manufacturer may correct minor surface defects by grinding, but the area limitations given in 5.2.2.3 of BS 6512 : 1984 shall apply.

Where defects are classified as type E in accordance with BS 6512, repair shall be followed by magnetic particle inspection or dye penetrant inspection.

9.1.2 Internal soundness for grades other than modified grades. For grades other than modified grades, plates shall be deemed to comply with the internal soundness of grade LC1 of BS 5996.

NOTE. Unless specified by the purchaser at the time of ordering, there is no obligation on the supplier to carry out ultrasonic testing. Option B.10 should be called up when ultrasonic testing is required to be undertaken by the supplier.

9.1.3 Internal soundness for modified grades. The internal soundness of all plates shall be verified by ultrasonic testing in accordance with BS 5996 and shall comply with grade L4 of BS 5996 for MZ grades and grade LC3 of BS 5996 for M grades. Ultrasonic testing shall be carried out in the final heat-treatment condition and with a probe frequency of 4 MHz.

Table 1. Maximum product CEV for plates, sections and seamless tubulars

Grade	Maximum CEV	Thickness
	%	mm
275D	0.41	Up to and including 20
275E 275EZ	0.39	Up to and including 40
355D	0.43	Up to and including 20
355E	0.43	Up to and including 40
355EM 355EMZ	0.43	Up to and including 40
	0.44	Over 40 up to and including 75
	0.45	Over 75 up to and including 150
450EM 450EMZ	0.43	Up to and including 75

9.2 Sections

9.2.1 Defects. All surfaces shall be 100 % visually inspected for defects. The material shall be sound and free from such internal and external defects or surface flaws as might preclude its use for the purpose for which it is intended.

9.2.2 Correction of minor defects. The manufacturer may remove minor surface defects by grinding but, in all cases, the thickness shall not be reduced locally by more than 3 mm and the final thickness shall not be more than 4 % below the minimum otherwise allowed by BS 4 : Part 1 and BS 4848 : Parts 4 and 5.

The total rectified area shall not exceed 50 000 mm² in any one square metre (5 %) without specific approval of the purchaser.

9.2.3 Repair by welding. Weld repair shall only be carried out with specific approval of the purchaser.

Where weld repairs are carried out, the defects shall be removed by grinding or chipping followed by magnetic particle inspection and then by welding subject to the following conditions.

(a) After complete removal of the defect and before welding, the thickness shall not have been reduced to less than 80 % of its nominal dimensions.

(b) The welding shall be carried out in accordance with BS 5135 by operators approved to BS 4871 : Part 1. The weld shall be ground smooth and flush with the adjacent surface of the product and subjected to non-destructive testing as specified by the purchaser. The manufacturer shall follow documented welding procedures established in accordance with BS 4870 : Part 1 and approved by the purchaser which are appropriate for the material being welded.

9.2.4 Internal soundness for modified grades. Rolled sections with a web thickness greater than 12 mm shall be subject to ultrasonic examination of webs and flanges when specified by the purchaser and shall meet the requirements of grade L3 of BS 5996.

NOTE. Testing of the region between the web and the flange should be subject to agreement between the supplier and the purchaser.

9.3 Seamless tubulars

9.3.1 Seamless tubulars shall be clean and free from such defects as can be established by visual inspection.

Visual inspection shall include the inside surface where practicable.

9.3.2 Surface marks and imperfections such as scabs, seams, tears, laps, slivers or gouges may be dressed by grinding and machining provided that the thickness of the seamless tube, after dressing, does not fall below the nominal thickness by more than the tolerance specified in 16.2.

Magnetic particle inspection shall be used to confirm removal of the defect.

9.3.3 All dressed areas shall blend smoothly into the contour of the seamless tube.

9.3.4 Seamless tubulars shall contain no dents greater than 3 mm or 1 % of the outside diameter, whichever is the lesser, when measured as the gap between the lowest point of the dent and a prolongation of the original contour of the seamless tubular. The length of the dent in any direction shall not exceed 25 % of the seamless tubular outside diameter.

All cold formed dents with a sharp bottom gouge shall be considered a defect and the gouge shall be removed by grinding.

9.3.5 All seamless tubulars shall be ultrasonically examined over the full length for laminar defects. The size of laminations shall be determined by manual ultrasonic examination and any seamless tubular containing a lamination exceeding 1000 mm² in area shall be deemed not to comply with this British Standard.

9.3.6 Ultrasonic testing of seamless tubulars shall be carried out for longitudinal defects and shall meet the supplementary requirements of API 5L except that the depth of the reference notch shall be 5 % of the thickness.

9.4 Ultrasonic, magnetic particle and dye penetrant inspection procedures

For implementation of non-destructive testing procedures and evaluation, all personnel shall be qualified to CSWIP level 3.1.P to 3.4.P (CSWIP-UST-5), or equivalent as appropriate. Magnetic particle inspection personnel shall be qualified to CSWIP-MAGPEN 4 or equivalent.

Where applicable ultrasonic testing shall be carried out in accordance with BS 5996, magnetic particle inspection (MPI) shall be carried out in accordance with BS 6072. The manufacturer shall submit written ultrasonic and magnetic particle inspection (MPI) and dye penetrant inspection procedures for approval prior to production of the order. These procedures shall include details of the following:

- (a) equipment to be used;
- (b) calibration standards;
- (c) frequency of calibration;
- (d) maintenance programmes;
- (e) operator qualifications;
- (f) reporting procedures;
- (g) frequency and size of probes (ultrasonic testing);
- (h) measurement of field strength (MPI);
- (i) maximum ultrasonic scanning speed.

See also option B.11.

10 Identification of cast

The manufacturer shall identify the ingots, billets, slabs, plates, steel sections and seamless tubulars, etc., in such a way as to enable the finished steel to be traced to the cast from which it was made.

11 Marking

11.1 Die stamping and paint marking

11.1.1 General. Die stamp digits shall be produced by round-nosed dies, shall be at least 8 mm high and shall be ringed with white paint for ease of identification. They shall be stamped on plates so that the letters are aligned at 90° to the principal direction of rolling. Paint marking shall be in white with digits at least 40 mm high. All markings shall be located in accordance with figures 1 to 3.

The following information shall be die stamped:

- (a) cast number;
- (b) if practicable, the supplier's plate/section/seamless tubular number;
- NOTE. This may not be possible at some section mills. This will be highlighted by the supplier at the time of the enquiry and order.
- (c) type of steel and grade;
- (d) manufacturer's brand mark;
- (e) certifying authority stamp (where appropriate).

The following information shall be paint marked:

- (f) purchase order number;
- (g) item size (thickness, width, length, section identification, diameter and wall thickness, etc.);
- (h) material grade;
- (i) principal rolling direction for plates (arrow);
- (j) purchaser's unique identification number (where applicable).

11.1.2 Bundling. For sections, bundling may be carried out for sizes 203 mm and below, but shall be restricted to material from one cast. Where sections are to be used for primary applications each individual section within a bundle shall be identified. When a bundle is split for re-distribution the relevant identification marks, in accordance with items (a) to (e), shall be transferred to the reconstructed bundles or to the individual items as appropriate.

11.2 Colour coding

Each plate shall be painted with either one or two 50 mm wide diagonal bands, depending on the grade, extending over the edges in accordance with figure 1.

Each section shall be painted with either one or two 50 mm wide bands, depending on the grade, along the longitudinal axis of the section and extending over the edges in accordance with figure 2.

NOTE. In the case of bundled sections it is sufficient to add splashes of paint to the ends of the bundles only.

See also option B.12.

Each seamless tubular shall be painted with either one or two 50 mm wide bands, depending on the grade, longitudinally along the external surface and extending over the edges as shown in figure 3.

See also option B.12.

Where two bands of the same colour are required they shall be separated by a minimum distance of 25 mm. The number and colour of bands shall be as follows:

grade 450EMZ	green	green
grade 450EM	green	—
grade 355EMZ	blue	blue
grade 355EM	blue	—
grade 355E	blue	white
grade 355D	blue	yellow
grade 275EZ	red	red
grade 275E	red	—
grade 275D	unpainted	—

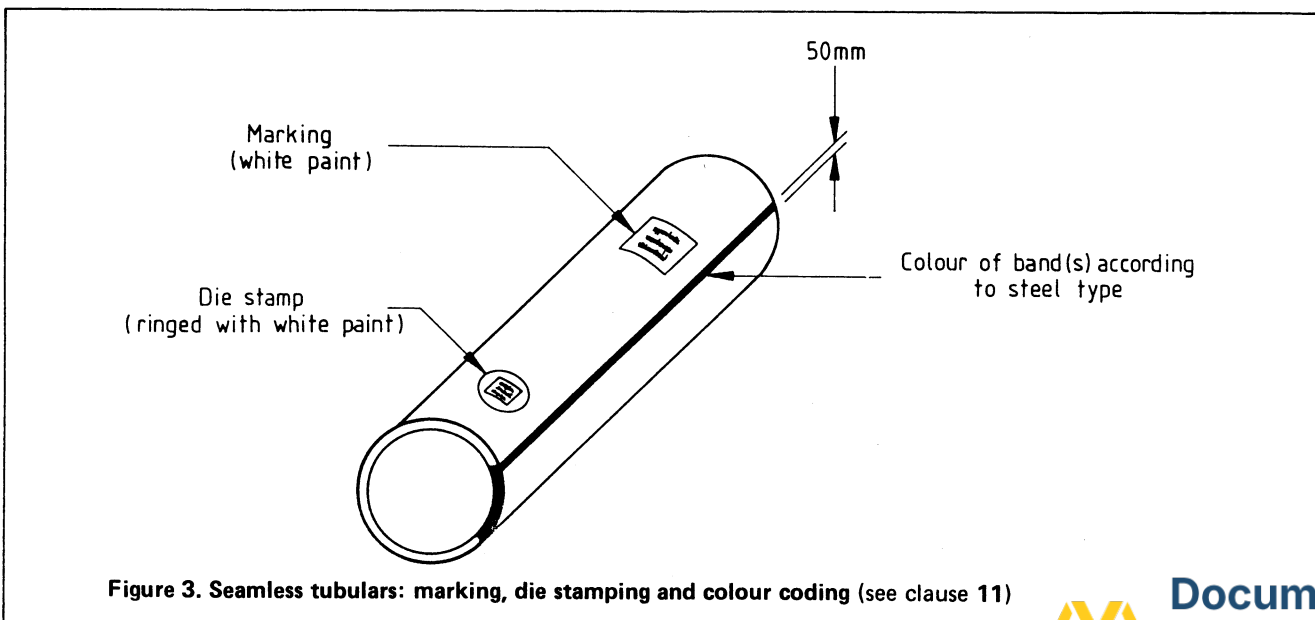
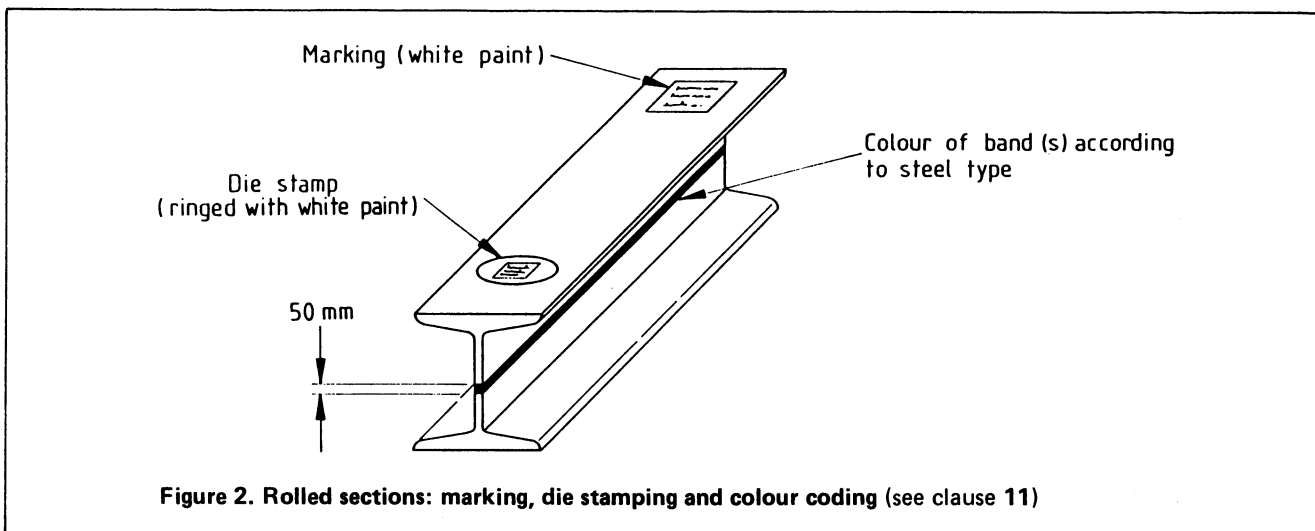
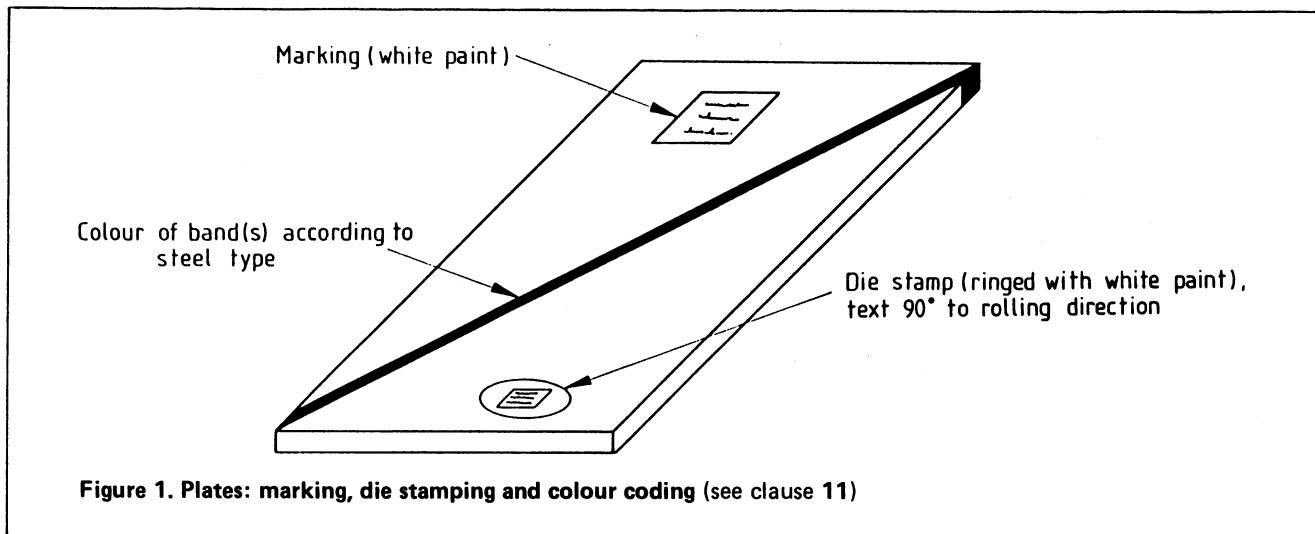
All paint for colour coding and stencil marking shall be applied to a clean, dry, oil-free surface and shall be able to resist weathering for at least 6 months and shall be commercially free from cadmium, lead, zinc, copper and tin.

The colour used for colour coding and marking shall be in accordance with the appropriate references of BS 5252, as summarized below:

blue	20E51
green	12D45
white	00E55
red	04E53
yellow	10E53

11.3 Protective coatings

All materials shall be supplied without the addition of protective surface coatings.



12 Test certificates

12.1 Ex-mill supply

One original of all relevant certificates and reports, clearly legible and in the English language shall be submitted to the purchaser at the time of despatch.

See also option B.13.

SI units shall be used on all documentation.

The mill certificates shall comply with DIN 50049 (3.1.B) and shall be acceptable to the certifying authority. They shall contain at least the following information.

(a) *Identification*, as follows:

- (1) mill location;
- (2) the purchaser's order and item number;
- (3) method of steel manufacture;
- (4) heat or cast number;
- (5) bar, bloom or plate number;
- (6) supply condition;
- (7) dimensions;
- (8) grade of steel.

(b) *Composition*, as follows:

- (1) ladle analysis;
- (2) product analysis;
- (3) carbon equivalent.

(c) *Heat treatment*, including details of heat treatment stating temperature, soaking times and cooling method;

NOTE. Records should be available at the mill for a period to be agreed with the purchaser.

(d) *Mechanical properties*, as follows:

- (1) yield strength, tensile strength, yield strength/tensile strength ratio, elongation;
- (2) Charpy V-notch impact test results;
- (3) through thickness properties (if required);
- (4) strain age test results (if required).

(e) *Nominal mass*.

(f) *Non-destructive test (NDT) results*, as follows:

- (1) verification of results of NDT are to be included on the test certificate;
- (2) the manufacturer's own results of NDT are to be endorsed by an operator approved under CSWIP-UST-5 or equivalent;
- (3) details of segregation control monitoring are to be given in a separate report.

In addition to items (a) to (f), the analysis of residual elements and the results of any additional testing deemed necessary by the purchaser shall be submitted in the form of separate reports.

12.2 Merchant supply

If any steel is supplied from a merchant's stock, the merchant shall be responsible for the following.

(a) Supplying to the purchaser a copy of the original order requirements placed on the mill and the subsequent sales history of the product.

(b) Supplying to the purchaser all documentation required by this standard including an original copy of the mill certificate (see 12.1) or a copy verified by the certification authority.

(c) Satisfying the purchaser by means of numbers or identification marks on the steel (or tab when parcels of steel are bundled) that such steel has been tested and complies with this standard, as applicable to the material specified, particularly where the dimensions or condition of the steel have been altered.

13 Delivery

At least 1 week prior to the start of delivery the supplier shall confirm with the purchaser the place for delivery of the steel.

Steel shall be delivered together with an accompanying advice note which shall contain the following minimum information:

- (a) mill location;
- (b) the purchaser's purchase order and item number;
- (c) cast number;
- (d) test/plate number;
- (e) the plate/seamless tubular/section sizes;
- (f) the material grade.

14 Mass of steel

The mass of plates, sections or seamless tubulars shall be calculated on the basis that the steel has a density of 7850 kg/m³.

Section two. Specific requirements for dimensional and shape tolerances

15 Tolerances for plates

15.1 General

Tolerances for plates produced on continuous mills shall comply with BS 1449 : Part 1.

Tolerances for plates produced on non-continuous mills shall comply with 15.2 to 15.6.

15.2 Length tolerances for plates

The length tolerances on ordered length for plates shall be as given in table 2. The length of a plate shall be taken as the length of the largest rectangle contained within the plate.

See also option B.14.

Table 2. Length tolerances for plates	
Ordered length	Tolerances
mm	mm
Less than 4 000	-0 +20
4 000 to less than 6 000	-0 +30
6 000 to less than 8 000	-0 +40
8 000 to less than 10 000	-0 +50
10 000 to less than 15 000	-0 +70
15 000 up to and including 20 000	-0 +100

15.3 Width tolerances for plates

The width tolerances on ordered width for plates shall be as given in table 3. Width shall be measured perpendicular to the major axis of the plate.

See also option B.14.

Table 3. Width tolerances for plates	
Ordered width	Tolerances
mm	mm
600 to less than 2 000	-0 +20
2 000 to less than 3 000	-0 +25
3 000 up to and including 4 000	-0 +30

15.4 Thickness tolerances

The thickness tolerances on ordered thickness of plates shall be as given in table 4. Thickness shall be measured at any point more than 15 mm from the edges of the plate.

See also options B.15 and B.16.

15.5 Edge camber for plates

Edge camber shall be limited so that it shall be possible to inscribe the dimensions of the ordered plate within the delivered size. The edge camber, *C*, shall be taken as the maximum deviation between one longitudinal edge and the straight line joining the two ends of this edge (see figure 4).

15.6 Flatness tolerances for plates

The flatness tolerances for plates shall not exceed the normal flatness tolerances given in table 5 for the straight-edge selected except that, for thicknesses of 50 mm and over, the flatness tolerance shall be based on a straightedge length of 2000 mm for all directions.

To measure flatness, the plate resting under its own weight shall be placed on a flat horizontal surface. Deviations with respect to flatness shall be determined by measuring the distance between the plate and a straightedge resting on the plate, the straightedge being placed in any direction.

Table 4. Thickness tolerances for plates					
Ordered thickness	Width of plate (in mm)				
	Up to and including 2 000	Over 2 000 up to and including 2 500	Over 2 500 up to and including 3 000	Over 3 000 up to and including 3 500	Over 3 500 up to and including 4 000
mm	mm	mm	mm	mm	mm
Less than 5	± 0.40	± 0.50	± 0.50	—	—
5 to less than 8	± 0.45	± 0.60	± 0.80	± 0.80	—
8 to less than 25	± 0.55	± 0.65	± 0.80	± 0.85	± 0.95
25 to less than 40	± 0.55	± 0.70	± 0.80	± 0.85	± 0.95
40 to less than 80	± 0.60	± 0.80	± 0.85	± 0.95	± 1.05
80 up to and including 150	± 1.10	± 1.15	± 1.20	± 1.25	± 1.25

Only the portion situated between the two points of contact shall be taken into consideration. Deviations shall be measured at a point a minimum of 20 mm from the longitudinal edges and a minimum of 100 mm from transverse edges. When distances between points of contact

are between 500 mm and 1000 mm, the deviation shall be obtained by taking the distance between points of contact and calculating proportionally from the deviation given for a 1000 mm straight edge in table 5.

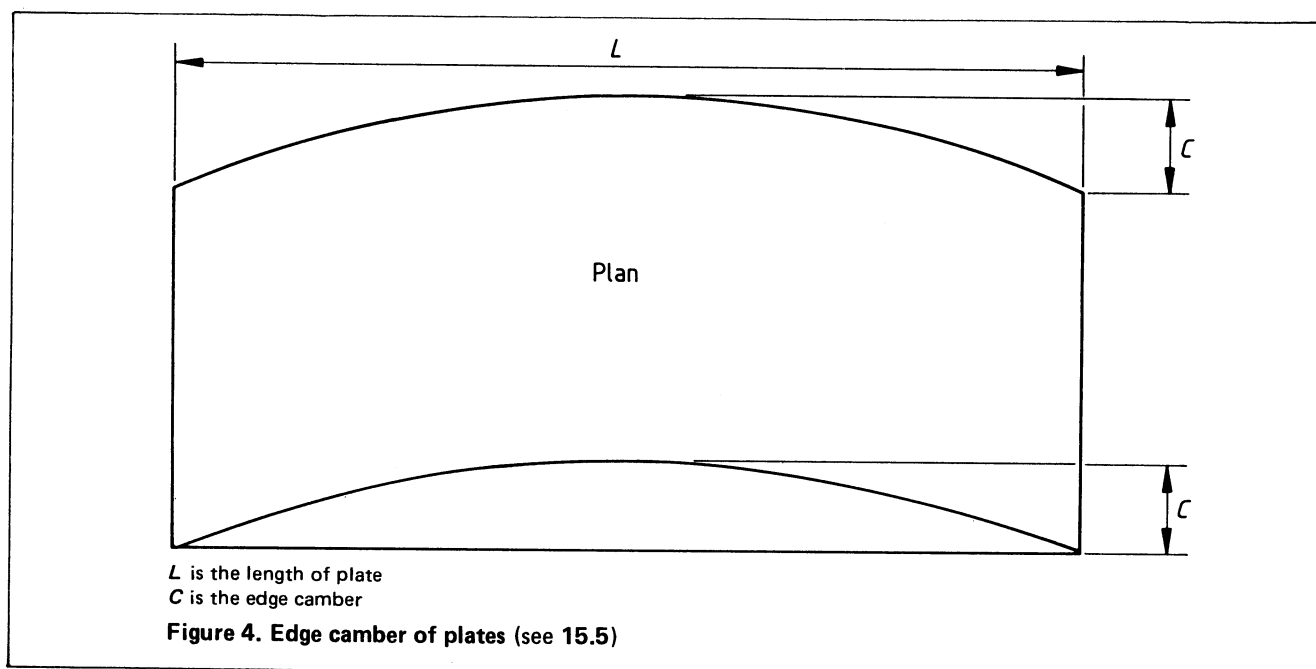


Table 5. Normal flatness tolerances for plates

Ordered thickness	Straightedge length selected	Permitted deviations for ordered widths (in mm)							
		Less than 1 500	1 500 to less than 2 000	2 000 to less than 2 500	2 500 to less than 2 750	2 750 to less than 3 000	3 000 to less than 3 250	3 250 to less than 3 500	3 500 to less than 4 000
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
3 to less than 4	1000 2000	7 14	8 18	10 22	— —	— —	— —	— —	— —
4 to less than 6	1000 2000	7 14	7 16	8 21	10 25	— —	— —	— —	— —
6 to less than 8	1000 2000	7 14	7 14	8 16	8 17	8 20	— —	— —	— —
8 to less than 10	1000 2000	7 13	7 13	7 14	7 15	8 16	8 18	9 20	— —
10 to less than 20	1000 2000	7 12	7 12	7 12	7 13	7 14	8 15	8 17	9 19
20 to less than 50	1000 2000	7 11	7 11	7 12	7 12	7 12	8 13	8 14	9 16
50 up to and including 150	2000	10	10	10	10	10	10	10	10

For ripples/corrugations less than 2 m apart (peak to peak) the following criteria shall apply.

- (a) The maximum depth of any ripple/corrugation under the 2 m straight edge shall be 5 mm. The average depth of all ripples on any one plate shall not exceed 4 mm.
- (b) The minimum depth to constitute a ripple/corrugation shall be 2 mm.
- (c) The maximum number of ripples/corrugations allowed in any one plate shall be as given in tables 6 and 7, and shall apply to all plates 10 mm thick and over and for all plate widths.

Table 6. Maximum number of ripples/corrugations in plate with thickness ≥ 12 mm	
Length	Maximum number of ripples/corrugations
m	
6	2
9	3
12	4
15	5

Table 7. Maximum number of ripples/corrugations in plate with thickness ≥ 10 mm < 12 mm	
Length	Maximum number of ripples/corrugations
m	
≤ 6	4
≤ 9	5
≤ 12	6
≤ 15	8

- (d) The flatness tolerance shall, in all cases, be measured to the upper surface of the plate laid on a level surface. See also option B.17.

16 Tolerances for sections and seamless tubulars

16.1 Sections

Rolling tolerances for sections shall comply with BS 4 : Part 1 and BS 4848 : Part 2.

Tolerances on specific lengths shall be $\begin{smallmatrix} -0 \\ +50 \end{smallmatrix}$ mm. The same tolerance shall still apply if the product is supplied in the normalized condition.

16.2 Seamless tubulars

The size, mass, length and straightness tolerances shall be as specified in BS 4848 : Part 2 and shall also apply if the product is heat treated. Ends of seamless tubulars shall be supplied square cut. Additionally, the tolerance on wall thickness shall be $\begin{smallmatrix} +15 \\ -12.5 \end{smallmatrix}$ %.

Seamless tubulars shall be supplied in the lengths defined in the purchase order with the above tolerances. Joints shall not be supplied.

Diameter and roundness shall be based on the nominal internal diameter, i.e. the specified outside diameter minus twice the nominal wall thickness. For a distance of 100 mm at both ends the internal diameter shall not deviate from the nominal internal diameter by more than ± 0.5 %.

Section three. Specific requirements for testing

17 Selection and identification of test samples for tensile and impact tests

17.1 Selection of samples

The manufacturer shall randomly select and identify test samples in accordance with clauses 18, 19, 22 and 23.

See also options B.18, B.19, B.20 and B.21.

17.2 Condition of samples

17.2.1 General. The test samples shall be in the heat-treatment condition specified in clause 6.

17.2.2 Modified grades

17.2.2.1 Grades 355EM and 355EMZ. For plates and seamless tubulars of thicknesses over 20 mm and piling of thicknesses over 65 mm, the test samples shall be subjected to a simulated post-weld heat-treatment (PWHT), at a nominal temperature of $600 \pm 20^\circ\text{C}$, for a minimum time of either 1 h per 25 mm thickness of plate, or 4 h, whichever is the greater. The test samples shall then comply with the minimum yield strength, tensile strength and impact properties given in tables 9 and 13.

See also option B.22.

17.2.2.2 Grades 450EM and 450EMZ. For plates and seamless tubulars of thickness over 20 mm, the test samples shall be subjected to a simulated post-weld heat-treatment, within the temperature range 550°C to 620°C with a maximum temperature of 25°C below the tempering range on the test certificate. The heat-treatment shall last for either 1 h per 25 mm thickness, or 4 h, whichever is the greater. The test samples shall then comply with the minimum yield strength, tensile strength and impact properties given in table 9 and table 13.

18 Number of tensile tests

One tensile test shall be made on the finished steel for each 40 t or part thereof of the same thickness range (see tables 9, 11 and 13), from the same cast, showing a thickness variation of not more than 5 mm above and below the thickness of the product sampled except that where ingot practice is used, one tensile test shall be made on each parent product.

19 Direction and position of tensile test samples

19.1 Direction of samples

19.1.1 Plates. Tensile test samples shall be cut with the longitudinal axis of the test samples transverse to the principal direction of rolling.

19.1.2 Sections and seamless tubulars. Tensile test samples shall be cut with the longitudinal axis of the test samples parallel to the principal direction of rolling.

19.2 Position of samples

19.2.1 Plates. Samples shall be taken from one end midway between the centre and one edge (see appendices C and D).

19.2.2 Sections. Samples shall be taken from the relevant flange positions shown in appendix C.

NOTE. In the case of sections with tapered flanges, the samples may be taken from the web or flange, at the manufacturer's discretion, as shown in appendix C.

19.2.3 Seamless tubulars. Samples may be taken from any location in the seamless tubular.

20 Tensile test pieces

20.1 Preparation of test pieces

Tensile test pieces shall be prepared in accordance with BS 18 from the test samples obtained in accordance with clauses 17 and 19 so that, wherever practicable, the rolled surface of the steel is retained on two opposite sides of the test piece. Where this is not practicable, round or rectangular test pieces having a diameter or thickness of not less than 12.5 mm shall be taken from the relevant position shown in appendix D.

20.2 Straightening of test pieces

Any straightening of test pieces which is required shall be done cold. Test pieces cut from seamless tubulars shall be tested in the curved condition, but the ends may be flattened cold for gripping.

21 Tensile test

21.1 General

The tensile test shall be carried out in accordance with BS 18. The tensile strength, R_m , the yield strength, R_e , and the elongation, A , shall be determined and the results obtained shall comply with the values given in tables 9, 11 and 13 for the appropriate grade.

NOTE. For the yield strength, the manufacturer may determine the upper yield stress, R_{eH} , or the 0.5 % proof stress (total extension), $R_{t0.5}$.

21.2 Dispute

If the result is in doubt or dispute, the yield strength shall be deemed not to be reached until the total extension under load, as determined by extensometer or dividers, is observed to be 0.5 % of the gauge length, i.e. 0.5 % proof stress (total extension), $R_{t0.5}$.

21.3 Elongation

Elongation shall be as given in tables 9, 11 and 13 and relates to an 80 mm gauge or 200 mm gauge length or a proportional gauge length of $5.65 \sqrt{S_0}$, where S_0 is the original cross-sectional area of the test piece.

If other gauge lengths are used, the corresponding elongation on a gauge length of 80 mm or 200 mm shall be obtained as described in BS 3894 : Part 1.

22 Number of impact tests

22.1 Plates

22.1.1 General. For steel grades 275D, 275E, 275EZ, 355 D and 355E, the test shall be made on three adjacent Charpy V-notch test pieces taken from one of the thickest plates of each 40 t or part thereof of the same thickness range (see table 9) from the same cast.

22.1.2 Modified grades. For steel grades 355EM, 355EMZ, 450EM and 450EMZ, the test shall be made on three adjacent Charpy V-notch test pieces taken from each parent product.

22.2 Seamless tubulars and sections

22.2.1 For steel grades 275D and 355D, the test shall be made on three adjacent Charpy V-notch test pieces taken from one of the thickest products of each 40 t or part thereof of the same thickness range (see tables 11 and 13) from the same cast.

22.2.2 For steel grades 275E, 275EZ, 355EM, 355EMZ and 450EM, the test shall be made on three adjacent Charpy V-notch test pieces taken from one of the thickest products for every 5 t or from each parent product if its mass exceeds 5 t.

23 Position of impact test samples

The impact test samples for plates and seamless tubulars shall be taken from positions as shown in appendix E. For sections the impact test samples shall be taken from within 25 mm of the centres of the positions shown in appendix E. For sections of non-uniform thickness longitudinal impact test samples shall be taken from the thickest part of the section at the locations shown in appendix E.

24 Impact test pieces

NOTE. Impact tests for material less than 6 mm are not normally carried out but may be agreed between the purchaser and the manufacturer at the time of the enquiry and order.

24.1 General

The test pieces shall be cut parallel or transverse to the principal direction of rolling as appropriate (see 24.5 and 24.6), and the axis of the notch shall be perpendicular to the rolled surface of the product (see figure 5). The test pieces shall be prepared in accordance with BS 131 : Part 2 and 24.2 to 24.4 of this standard.

24.2 Material 20 mm thick and over

For material of thicknesses of 20 mm and over, standard 10 mm × 10 mm test pieces shall be machined so that they do not include material nearer to the surface than 3 mm.

24.3 Material equal to or greater than 12 mm thick up to but excluding 20 mm

For material equal to or greater than 12 mm thick and up to but excluding 20 mm thick, standard 10 mm × 10 mm test pieces shall be machined so that they do not include material nearer to the surface than 1 mm.

24.4 Material equal to or greater than 6 mm thick but less than 12 mm thick

For material equal to or greater than 6 mm thick and up to but not including 12 mm thick, one of the following sizes of test pieces shall be prepared using the full thickness where necessary:

- (a) standard test piece, 10 mm × 10 mm;
- (b) subsidiary standard test piece, 10 mm × 7.5 mm;
- (c) subsidiary standard test piece, 10 mm × 5 mm.

24.5 Plates of general and modified grades

The test pieces shall be taken from the following positions:

- (a) the sub-surface, as specified in 24.2 and 24.4 for all grades;
- (b) mid-thickness, when the thickness is above 40 mm for modified grades only.

Charpy V-notch test pieces shall be cut parallel to the principal direction of rolling for grades 275D, 275E, 275EZ, 355D and 355E and transverse to the principal direction of rolling for grades 355EM, 355EMZ, 450EM and 450EMZ (see figure 5).

24.6 Sections and seamless tubulars

Charpy V-notch test pieces shall be cut parallel to the principal forming direction for all grades.

25 Impact tests

25.1 Method of testing

The impact test shall be carried out in accordance with BS 131 : Part 2 at the temperature given in tables 9, 11 and 13 for the grade ordered. For piling material the impact tests at mid-thickness shall be carried out at -30 °C instead of -40 °C.

25.2 Values for standard test pieces

The average impact value obtained from three standard 10 mm × 10 mm test pieces shall be not less than the appropriate value given in tables 9, 11 and 13 for the grade ordered (see also 25.4).