

Steel, concrete and composite bridges —

Part 6: Specification for materials and workmanship, steel

ICS 93.040

Committees responsible for this British Standard

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- British Precast Concrete Federation Ltd.
- British Railways Board
- British Waterways Board
- Concrete Society
- County Surveyors' Society
- Department of Transport (Highways Agency)
- Steel Construction Institute
- Welding Institute

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Foreword

This part of BS 5400 has been prepared by Subcommittee B/525/10. It supersedes BS 5400-6:1980 which is withdrawn.

This new edition incorporates technical changes only; it does not constitute a full review or revision of the standard which will be undertaken in due course.

BS 5400 is a document combining codes of practice to cover the design and construction of steel, concrete and composite bridges and specifications for loads, materials and workmanship. It comprises the following parts and sections:

- *Part 1: General statement;*
- *Part 2: Specification for loads;*
- *Part 3: Code of practice for design of steel bridges;*
- *Part 4: Code of practice for design of concrete bridges;*
- *Part 5: Code of practice for design of composite bridges;*
- *Part 6: Specification for materials and workmanship, steel;*
- *Part 7: Specification for materials and workmanship, concrete, reinforcement and prestressing tendons;*
- *Part 8: Recommendations for materials and workmanship, concrete, reinforcement and prestressing tendons;*
- *Part 9: Bridge bearings;*
 - *Section 9.1: Code of practice for design of bridge bearings;*
 - *Section 9.2: Specification for materials, manufacture and installation of bridge bearings;*
- *Part 10: Code of practice for fatigue.*

This publication does not purport to include all the necessary provision of a contract. Users are responsible for their correct application.

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 38, an inside back cover and a back cover.

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1 Scope

This part of BS 5400 specifies requirements for the materials, workmanship, handling and erection for the construction of steel bridges.

NOTE The requirements specified herein are suitable for inclusion in contract documents.

2 Normative references

This part of BS 5400 incorporates by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on page 36. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this part of BS 5400 only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the publication applies, together with any amendments.

3 Materials

3.1 Structural steels

3.1.1 *Structural steels complying with the requirements of designated standards*

Structural steels shall comply with the requirements of BS EN 10025, BS EN 10113, BS EN 10137, BS EN 10155, BS EN 10210 or BS 7668, as appropriate, unless otherwise specified by the Engineer, and shall be of one of the grades specified therein. Unless otherwise specified, the ladle analysis for each grade of steel shall be supplied. Where specified by the Engineer the maximum carbon equivalent values for each grade of steel shall not exceed the values specified in these designated standards.

3.1.2 *Structural steels complying with the requirements of other specifications*

Where structural steels complying with the requirements of specifications other than the standards designated in 3.1.1 are either specified by the Engineer or are offered in place of steels that comply with the requirements of the standards designated in 3.1.1, the performance requirements listed in Table 1 shall comply with those specified in the standards designated in 3.1.1; this shall be demonstrated by testing in accordance with the requirements of the standards designated in 3.1.1. Rimming steel shall not be used.

Table 1 — Performance requirements for structural steels

Performance requirement	Indicated as
Yield strength	Yield stress
Minimum tensile strength	Minimum tensile strength
Notch toughness	Average minimum Charpy energy value at specified temperature
Ductility	Elongation in a specified gauge length
Weldability	Maximum carbon equivalent value
Quality of finished steel	Complying with the requirements of the standards designated in 3.1.1

3.1.3 *Notch toughness*

The grade of steel to meet the notch toughness requirements shall be as specified by the Engineer.

3.1.4 Laminar defects

3.1.4.1 The following areas of plates shall not have laminations exceeding the following limits:

- a) for a band of flange or web plate of width 25 times the plate thickness each side of a bearing diaphragm where attached by welding: acceptance level B4 of BS 5996:1993;
- b) for a band of web plate of width 25 times the plate thickness on each side of a single sided bearing stiffener where attached by welding: acceptance level B4 of BS 5996:1993;
- c) for edges of plates where corner welds will be made on to the surface of such plates: acceptance level E of BS 5996 :1993;
- d) for welded cruciform joints transmitting primary tensile stresses through the plate thickness, on a band of width four times the thickness of the plate each side of the proposed attachment: acceptance level B4 of BS 5996:1993.

3.1.4.2 For welded cruciform and toe joints the material used shall not contain laminations of such an extent in the region of the weld as to prevent compliance with the limits specified in **5.5.2.4.2**.

3.1.4.3 Where specified by the Engineer, other areas of plate shall not have laminations exceeding the limits of the appropriate acceptance level given in BS 5996.

3.1.5 Marking

Steel shall be marked in accordance with the requirements of the standards designated in **3.1.1**. Where steels of differing grades are used in the same contract, they shall have additional markings as specified by the Engineer.

3.1.6 Manufacturer's inspection document

The steel supplier shall supply the Engineer with an inspection document relating to specific inspection and testing in accordance with BS EN 10204:1991, Inspection Certificate 3.1.B.

3.1.7 Thickness tolerance of plates

The total thickness tolerance of plates shall be in accordance with Class A of BS EN 10029:1991.

3.1.8 Hot rolled sections

Hot rolled sections shall be in accordance with BS EN 10034 or BS EN 10056-2, as appropriate.

3.2 Rivet steels

Steel rivet bars for the manufacture of structural rivets shall, unless otherwise specified by the Engineer, comply with the requirements of Annex A.

3.3 Steel for shear connectors

Steel for headed stud type shear connectors shall have a minimum yield stress of 385 N/mm², a minimum tensile strength of 495 N/mm² and a minimum elongation of 15 % prior to the cold formation of the head. Steel for other types of shear connectors, shall, unless otherwise specified by the Engineer, comply with the requirements of the standards designated in **3.1.1**.

3.4 Bolts, nuts and washers

3.4.1 Structural steel bolts and nuts

Unless otherwise specified by the Engineer, assemblies of structural steel bolts and nuts shall correspond to one of the matching combinations given in Table 2, and the materials shall comply with the requirements of the appropriate standards given in Table 2.

Holding down bolt assemblies shall comply with the requirements of BS 7419.

3.4.2 Plain washers

Black steel plain washers shall comply with the requirements of section 2 of BS 4320:1968, normal diameter series.

3.4.3 High strength friction grip bolts, nuts and washers

Unless otherwise specified by the Engineer, high strength friction grip bolts, nuts and washers shall comply with the requirements of BS 4395. Direct tension indicators shall comply with BS 7644.

Table 2 — Matching structural bolts and nuts

Type of bolts		Nuts	
Grade	Standard	Class or grade ^c	Standard
4.6	BS EN 24016 BS EN 24018	Class 4 ^d	BS EN 24034
4.6 (countersunk)	BS 4933 ^a	Grade 4	BS 4190 ^a
8.8	BS EN 24014 ^b BS EN 24017 ^b	Class 8 ^e	BS EN 24032 ^b
10.9	BS EN 24014 ^b BS EN 24017 ^b	Class 10 ^f	BS EN 24032 ^b

^a BS 4933 has been declared obsolescent, but shall still be used for 90° countersunk head bolts and cup head bolts until corresponding BS EN standards are available. The nuts to be used with bolts to this standard shall be in accordance with BS 4190, although that standard has also been declared obsolescent.

^b Grade 8.8 and 10.9 bolts to the strength grades of BS EN 24014 or BS EN 24017 but the dimensions and tolerances of BS EN 24016 or BS EN 24018 may also be used, with matching nuts to the strength classes of BS EN 24032 but the dimensions and tolerances of BS EN 24034.

^c Nuts of a higher class or grade may also be used.

^d Class 5 nuts for size M16 and smaller.

^e Class 10 nuts for galvanized, sherardized or electroplated 8.8 bolts.

^f Class 12 nuts to BS EN 24033 for galvanized, sherardized or electroplated 10.9 bolts.

3.5 Welding consumables

Welding consumables used in metal-arc welding of grades of steel complying with the requirements of the standards designated in 3.1.1 shall comply with the requirements of BS 5135. Welding consumables used in the fusion welding of steel castings shall comply with the requirements of BS 4570.

Unless otherwise agreed with the Engineer, the consumables and procedures used shall be such that the yield and tensile strengths of deposited weld metal shall not be less than the respective minimum values of the parent metal being welded.

3.6 Rolled steel pins

Rolled steel pins, including those made from slabs, shall comply with the requirements of BS 970, BS EN 10083-1 or the standards designated in 3.1.1.

3.7 Steel castings and cast steel pins

Carbon manganese steelcastings shall comply with the requirements of BS 3100.

3.8 Steel forgings and forged steel pins

Steel forgings and forged steel pins shall comply with the requirements of BS 29 and shall have the appropriate tensile strength given therein.

3.9 Stainless steel

Stainless steel shall comply with the requirements of BS EN 10088. The quality shall normally be of the 16 % to 19 % chromium 8 % to 12 % nickel austenitic type.

3.10 Cast iron

3.10.1 Grey cast iron

Grey cast iron shall comply with BS EN 1561:1997, Grade EN-GJL-150, except that when stronger cast iron is required for special purposes it shall comply with a higher grade of BS EN 1561 as specified by the Engineer.

3.10.2 Malleable cast iron

Malleable cast iron shall comply with the requirements of BS EN 1562:1997, Grades EN-GJMW-350-4, EN-GJMW-360-12, EN-GJMW-400-5 or EN-GJMB-350-10, as appropriate.

3.10.3 Spheroidal or nodular cast iron

Spheroidal or nodular cast iron shall comply with the requirements of BS EN 1563 for the grade specified.

4 Workmanship

4.1 Interchangeability of parts

Unless specified by the Engineer, corresponding parts need not be interchangeable.

4.2 Fabrication tolerances

4.2.1 General

All parts in an assembly shall fit together accurately within the tolerances specified in 4.2.2, 4.2.3 and 4.2.4 and in Table 8.

4.2.2 Rolled and built-up sections

Unless otherwise agreed by the Engineer, all components of rolled and built-up sections (other than those with curved flanges with a radius of curvature less than 25 times the spacing of cross frames) shall be fabricated within the tolerances given in Table 8.

4.2.3 Flatness of a machined bearing surface

Where a machined bearing surface is specified by the Engineer, it shall be machined within a deviation of 0.25 mm for surfaces that can be inscribed within a square of side of 0.5 m.

4.2.4 Alignment at splices and butt joints

4.2.4.1 Bolted splices

All bolted splices shall be provided with steel packing plates, where necessary, to ensure that the sum of any unintended steps between adjacent surfaces does not exceed 1 mm for HSFG bolted joints and 2 mm for other joints.

4.2.4.2 Welded butt joints

Any unintended deviation from planarity due only to a misalignment of parts to be joined shall not exceed the lesser of 0.15 times the thickness of the thinner part or 3 mm. However, if, due either to different thicknesses arising from rolling tolerances or a combination of rolling tolerances with the above permitted misalignment, this deviation exceeds 3 mm, it shall be smoothed by a slope not steeper than 1 in 4.

4.3 Preparation of edges, ends and surfaces

Any burring, abnormal irregularities or scales shall be removed.

4.3.1 Edges

Edges shall be either:

- a) left as rolled, sawn, machined, machine flame cut (see 4.3.3); or
- b) hand flame cut (see 4.3.3) with subsequent grinding to a smooth profile; or
- c) for stiffeners and gussets, both not more than 12 mm thick, sheared and subsequently ground to a smooth profile.

4.3.2 Ends

Ends shall be either:

- a) sawn, machined, machine flame cut (see 4.3.3); or
- b) hand flame cut (see 4.3.3) with subsequent grinding to a smooth profile; or
- c) for stiffeners, of not more than 12 mm thick, sheared and subsequently ground to a smooth profile.

If ends of stiffeners are required to be fitted they shall be ground, where necessary, so that the maximum gap over 60 % of the contact area does not exceed 0.25 mm.

4.3.3 Flame cutting and shearing

Where flame cutting or shearing, as specified in 4.3.1 and 4.3.2 is used at least one of the following requirements shall be satisfied:

- a) the hardness of the cut edge does not exceed 350 HV 30 when tested in accordance with BS EN ISO 6507;
- b) the cut edge is not subjected to applied stress;
- c) the cut edge is wholly incorporated in a weld;
- d) the material from the edge is removed by grinding or machining to the extent of either 2 mm, or the minimum necessary to demonstrate that the hardness on the edge does not exceed 350 HV 30 when tested in accordance with BS EN ISO 6507;
- e) the edge is softened by a suitable heat treatment approved by the Engineer and is shown by dye penetrant or magnetic detection procedure to be free from cracks;
- f) the material is grade 43 steel and is not greater than 40 mm thick and edge preparation is by machine flame cutting.

In addition to the requirements of a) to f) where specified by the Engineer the flame cut edges shall be ground or machined to remove all visible signs of drag lines.

4.3.4 Machining at butted joints

Where machining of surfaces at butted joints is specified, the abutting ends of the parts shall be machined after the members have been fabricated.

4.3.5 Treatment of outside arrises

Outside arrises of plates and sections, which are to receive corrosion protection, shall be smoothed by grinding or filing.

4.3.6 Contact surfaces for high strength friction grip bolted connections

Except where otherwise specified by the Engineer, all contact surfaces in high strength friction grip bolted connections shall comply with the requirements of BS 4604. Where a particular treatment is specified for faying surfaces, the treated surfaces shall be adequately protected until they are brought together.

4.4 Bolts, nuts and washers

The requirements of 4.4.1 to 4.4.5 shall apply unless otherwise specified or approved by the Engineer.

4.4.1 Structural steel bolts and nuts

Structural steel bolts and nuts shall comply with the requirements of the appropriate standards in Table 2.

4.4.2 Close tolerance bolts

Close tolerance bolts shall comply with the requirements of BS EN 24014. Nuts for close tolerance bolts shall comply with BS EN 24032.

4.4.3 Turned barrel bolts

The diameter of the screwed portion of turned barrel bolts shall be at least 2 mm smaller than the diameter of the barrel. The specified diameter of the bolts shall be the nominal diameter of the barrel.

The diameter of the turned barrel shall be within the diameter tolerances for bolts as specified in BS EN 24014. The length of the barrel shall be such that it bears fully on all the connected parts.

4.4.4 High strength friction grip bolts, nuts and washers

Except as specified in 4.2.4.1, compliance and use requirements for high strength friction grip bolts shall be as given in Table 3 unless otherwise specified by the Engineer.

Table 3 — Requirements for high strength friction grip bolts

HSFG bolts	Complying with the requirements of	Use according to the requirements of
General grade	BS 439-1	BS 4604-1
Higher grade, parallel shank	BS 4395-2	BS 4604-2

4.4.5 Washers

Where necessary, a steel washer shall be provided to prevent the nut binding on the shank of the bolt. Where the full bearing area of the shank of the bolt is to be developed, the threaded portion of the bolts shall not extend within the thickness of the connected parts.

For turned barrel bolts, a steel washer with true bearing faces shall be provided under the nut. The washer shall have a hole diameter nominally 1.5 mm larger than the barrel and a thickness of not less than 6 mm.

Tapered washers of the nominally correct angle of taper shall be provided under all heads and nuts bearing on bevelled surfaces.

4.5 Holes for rivets and bolts

4.5.1 Holes for rivets, countersunk bolts and black bolts (excluding close tolerance and turned barrel bolts)

The diameter of holes shall be 2 mm larger than the nominal diameter of the cold rivet or bolt as manufactured. All holes shall be drilled or shall be drilled small and reamed or sub-punched and reamed, except that for floor plates and troughing not exceeding 12 mm in thickness and elsewhere, as approved by the Engineer, the holes may be punched full size.

Where several plates or sections form a compound member they shall, where practicable, be firmly connected together by clamps or service bolts and the holes drilled through all the thicknesses at one operation, or alternatively, and in the case of repetition work, the plates and sections may be drilled separately from jigs or templates. All burrs shall be removed.

4.5.2 Holes for close tolerance bolts and turned barrel bolts

The diameter of the holes shall be equal to the nominal diameter of the bolt shank or barrel, subject to a tolerance of +0.15 mm and -0 mm.

Preferably, parts to be connected with close tolerance or turned barrel bolts shall be firmly held together by service bolts or clamps and the holes drilled through all the thicknesses at one operation and subsequently reamed to size if necessary, in order to provide true holes within the specified limits of accuracy. All holes not drilled through all thicknesses at one operation shall be drilled to a smaller size and reamed out after assembly. Where this is not practicable, the separate parts shall be drilled through hard bushed steel jigs and reamed if necessary. All burrs shall be removed.

4.5.3 Holes for high strength friction grip bolts

Unless otherwise specified by the Engineer, holes for high strength friction grip bolts shall comply with the requirements of BS 4604.

4.6 Rivets and riveting

The dimensions of rivets shall comply with the requirements of BS 4620. Wherever possible, the rivets shall be driven by pressure machines. The driving pressure shall be maintained on the rivet for a short time after the upsetting is completed. Each rivet shall be of sufficient length to form a head of the standard dimensions, shall be at red heat from head to point when inserted and shall be upset in its entire length when hot so as to fill the hole as completely as possible.

Each rivet shall be freed from scale by striking the hot rivet on a hard surface after being heated and before being inserted in the hole.

When countersunk heads are required, the heads shall fill the countersink. Unless otherwise specified by the Engineer, the heads shall conform to the dimensions of rounded or flat countersunk heads specified in BS 4620.

Where a flush surface is required, any projecting metal shall be chipped or ground-off.

Before riveting is commenced all work shall be properly bolted-up so that the various sections and plates are in close contact throughout. Drifts shall be used only for drawing the work into position and shall not be used to such an extent as to distort the holes. Drifts of a larger size than the nominal diameter of the hole shall not be used.

4.7 Welding

4.7.1 *Welding of structural steels*

Unless otherwise specified by the Engineer, metal-arc welding shall comply with the requirements of BS 5135. The use of welding processes other than those specified in BS 5135 shall be subject to the approval of the Engineer.

The general welding procedures for shop and site welds, including particulars of the preparation of fusion faces, shall be submitted, in writing, in accordance with the requirements of BS 5135, for the approval of the Engineer before commencing fabrication. No departure from the approved welding procedure or from the details shown on the drawings shall be made without the approval of the Engineer.

For those areas specified by the Engineer, the method of making any temporary attachments shall be agreed with the Engineer. Any scars from temporary attachments shall be made good to the satisfaction of the Engineer. Where weld repairs are necessary these shall be carried out in accordance with the requirements of BS 5135.

Visible weld surfaces shall be cleaned of slag residues. All weld spatter shall be removed and affected surfaces shall be dressed and cleaned.

Where the Engineer has specified that the butt welds are to be ground flush, the loss of parent metal shall not be greater than that allowed for the correction of minor surface defects specified in the standards designated in 3.1.1.

To enable full throat thickness to be provided at the ends of butt welded joints “run-on” and “run-off” plate extension pieces shall be used. “Run-on” plates and “run-off” plates shall comply with the following requirements.

- a) One pair of “run-on” plates and one pair of “run-off” plates prepared to the same thickness and profiles as the parent metal shall be attached, preferably by clamps, to the start and finish of all butt welds.
- b) Butt welds shall extend at the full weld profile for a minimum distance of 25 mm into both the “run-on” and the “run-off” plates.
- c) When removing the “run-on” and “run-off” plates by flame cutting, the cuts shall not be nearer than 3 mm to the sides of the parent metal and the remaining metal shall be removed by grinding or another method agreed by the Engineer.

4.7.2 *Welding of steel castings*

Unless otherwise specified by the Engineer, fusion welding of steel castings shall comply with the requirements of BS 4570.

The proposed welding procedures shall be submitted in writing, in accordance with the requirements of BS 4570 for the approval of the Engineer before commencing welding of steel castings. No departures from the agreed welding procedures or from the details shown on the drawings shall be made without the approval of the Engineer.

4.7.3 *Welding, flame cutting and shearing procedure trials*

When specified by the Engineer and before fabrication is commenced, welding, flame cutting and shearing trials shall be carried out using representative samples of materials to be used in the work. The samples of materials shall be agreed with the Engineer.

The welding, flame cutting and shearing trials shall demonstrate to the satisfaction of the Engineer the procedures to be adopted in the fabrication of the work, which shall include the following:

- a) welding procedures complying with the requirements of BS 5135, BS EN 288-1, -2 and -3, and BS 4570, as appropriate;
- b) flame cutting and shearing techniques complying with the requirements of 4.3.3.

Where primers are to be applied to the work prior to fabrication, they shall be applied to the sample material before the procedure trials are made.

4.7.4 Stud shear connectors: welding and procedure trials

Stud shear connectors shall be welded in accordance with the manufacturer's instructions, including preheating where necessary. Welding shall not be carried out when the ambient temperature is below 0 °C or when the surface is wet. The studs and the surface to which the studs are welded shall be free from scale and rust, metal spray, grease, oil, paint or other material which would affect the quality of the weld.

The welds shall be visually free from cracks and lack of fusion and shall be capable of developing at least the nominal ultimate strength of the studs.

When specified by the Engineer and before production welding of studs commences, procedure trials shall be carried out. The trials shall be made on samples of material and studs representative of those to be used in the work. The samples of materials and studs shall be agreed with the Engineer.

Where primers are to be applied to the work prior to the welding of studs they shall be applied to the sample material before the procedure trials are made.

4.7.5 Repair of unacceptable weld discontinuities

Weld discontinuities which are not acceptable according to 5.5.2 shall be removed by grinding or repaired by welding as appropriate, but not before the rectification procedure has been approved by the Engineer. The preparation for weld repairs shall be by grinding, chipping or air-arc gouging followed by grinding and proved free of exposed defects using magnetic particle inspection in accordance with BS 6072 prior to rewelding.

The whole of the repaired length of the joint shall be inspected using the non-destructive testing methods and criteria for acceptance specified for the original weld.

4.8 Bending and pressing

Steel may be bent or pressed to the required shape by either the hot or the cold process, provided the properties of the material are not affected beyond the limits specified in the standards designated in 3.1.1. For cold bending the internal radius of bends shall not be less than twice the metal thickness. For hot bending the temperature, timing and cooling rate shall be appropriate to the particular type of steel and shall be agreed with the Engineer; accelerated cooling shall not be used without the approval of the Engineer.

4.9 Straightening and flattening

Hammering shall not be permitted. Where heating is used either the temperature of the steel shall not exceed 650 °C, or the temperature, timing and cooling rate shall be appropriate to the particular type of steel and shall be agreed with the Engineer; accelerated cooling shall not be used without the approval of the Engineer.

4.10 Forging

Forging shall be carried out in such a manner that it will not impair the strength of the metal.

4.11 Tie rods

Tie rods with upset ends and plus threads and tie rods with forged eyes shall be formed by being pressed up in a die or by another method approved by the Engineer. Where agreed by the Engineer, suitably designed flame cut or forged eyes or machined stub ends may be metal-arc welded or resistance welded to the rods. Hot forming shall be carried out in such a way that it will not impair the strength of the metal.

4.12 Parallel barrel drifts

The barrel shall be drawn or machined to the required diameter for a length of not less than one diameter over the combined thickness of the metal through which the drift has to pass. The diameter of the parallel barrel shall be equal to the nominal diameter of the hole subject to a tolerance of -0.05 mm to -0.20 mm. Both ends of the drift, for a length equal to 1.5 times the diameter of the parallel portion of the bar, shall be turned down with a taper to a diameter at the end equal to 0.5 times that of the parallel portion.

4.13 Pins and pin holes

Pins shall be parallel throughout and shall have a smooth surface free from flaws. They shall be of sufficient length to ensure that all parts connected thereby will bear fully on them. Where the ends are threaded they shall be turned to a similar diameter and shall be provided, where necessary, with a pilot nut to protect the thread.