British Standard

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Steel, concrete and composite bridges —

Part 6: Specification for materials and workmanship, steel

ICS 93.040

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Committees responsible for this British Standard

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British Iron and Steel Producers Association

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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Contents

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 It supersedes BS 5400:-6:1980 which is withdrawn.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/mm^2, a minimum tensile strength of 495 N/mm^2 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 though 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.

The pin holes shall be bored smooth, straight and true to gauge and at right angles to the axis of the member. Boring shall be done only after the member is finally riveted, bolted or welded unless otherwise agreed with the Engineer.

For pins up to and including 250 mm diameter, the diameter of the pins shall be within a tolerance of−0.25 mm to −0.40 mm and the diameter of the pin hole shall be within a tolerance of 0 mm to +0.15 mm.

For pins exceeding 250 mm diameter, the clearance between the pin and the pin hole shall be not less than 0.40 mm and not more than 0.75 mm.

4.14 Camber

Camber may be formed by connecting straight sections of girder with change of slope at their junctions, unless otherwise specified by the Engineer.

4.15 Marking for erection

Every part shall be marked for erection with a durable and distinguishing mark in such a way as not to damage the material. Drawings showing the marking scheme shall be supplied to the Engineer. Where parts which have been erected at the contractor's works are connected with close tolerance or turned barrel bolts, the members shall be match marked to ensure final assembly in the same position. Where specified by the Engineer, hard stamping shall not be used.

4.16 Rectification of surface defects and edge laminations

Surface defects revealed during fabrication or blast cleaning shall be treated in accordance with the requirements of the standards designated in **3.1.1**. Repair by welding of any surface defect or exposed edge lamination shall only be carried out with the approval of the Engineer and using a procedure complying with the requirements of BS 5135.

5 Inspection and testing

5.1 General

No protective treatment other than prefabrication primer shall be applied to the work until the appropriate inspection and testing has been carried out.

5.2 Testing of structural steel

5.2.1 *General*

All tests on structural steel shall comply with the requirements of the standards designated in **3.1.1**.

5.2.2 *Acceptance levels for laminations*

Ultrasonic testing by the methods given in BS 5996 shall be carried out either at the steel mills or by the fabricator in his own works before fabrication, to test the areas specified in **3.1.4** for laminations.

NOTE Flame cut edges without visual signs of laminations need not be tested for compliance with **3.1.4.1**c).

5.3 Surface defects and edge laminations

Steelwork shall be inspected for surface defects and exposed edge laminations during fabrication and blast cleaning. Significant edge laminations found shall be reported to the Engineer for his decision.

Following rectification of these affected areas they shall be tested for defects to the satisfaction of the Engineer.

5.4 Procedure trials

5.4.1 *Testing of welding for structural steels*

5.4.1.1 *Non-destructive and destructive testing*

With the exception of all weld tensile tests, non-destructive and destructive testing of welding shall be carried out as specified in BS EN 288-3. The root bend and face bend tests specified in BS EN 288-3 shall have the weld root and the weld face respectively in tension as described in the transverse bend tests of BS EN 910. Additionally, hardness tests shall be carried out on weld metal, heat affected zone and parent material of a macrosection from each weld procedure test sample, and the results recorded and submitted to the Engineer.

Charpy V-notch impact tests for butt welds and heat affected zones of butt welds shall be carried out as specified in **5.4.1.2**.

5.4.1.2 *Weld metal and heat affected zone (HAZ) Charpy V-notch impact test requirements for tension areas*

a) *Weld metal in butt welds including corner or T-butt welds parallel or transverse to the main tension stress.* The minimum Charpy energy absorption requirements and the test temperature shall be the same as that specified by the engineer for the parent material joined. In the case of parent materials on each side of the joint which have different specified Charpy requirements, the weld metal requirements shall be those of the parent material with the lower test temperature or, in the event that the test temperatures are the same, the higher energy absorption requirement.

b) *Heat affected zone (HAZ).* The fusion boundary region of the HAZ of butt welds, including corner or T-butt welds, which are transverse to and carry the main tension stress shall have the notch ductility requirements given in Table 4.

c) *Location and orientation of specimens and orientation of notch.* For Charpy tests on the weld metal the length of specimen shall be taken transverse to the line of the weld and the specimens notched so that the line of the notch root is perpendicular to the plate surface and is on the centre line of the weld joint. For symmetrical and asymmetrical double V, double J and double bevel joint preparations the specimen shall be cut so that one face is substantially parallel to, and within 3 mm of, the surface of the weld. Additionally for the asymmetric preparation the specimen shall be taken from the side with the smaller preparation. For single V, single J and single bevel joint preparations the specimen shall be cut so that one face is substantially parallel to and within 3 mm of the root surface of the weld.

For Charpy tests in the fusion boundary region of the HAZ, specimens shall be taken with their length transverse to the line of the weld and notched so that the line of the notch root is perpendicular to the original plate surface. As far as possible, the notch at mid-thickness of the specimen should lie on the fusion boundary of the HAZ of the weld under test. The specimens shall be cut so that one face is substantially parallel to, and within 3 mm of, the original plate surface.

d) *Number of specimens*. Initially, three specimens for each weld or HAZ under consideration shall be taken and depending on the test results for these specimens [see e) below] a further three specimens may be taken from the same joint.

e) *Testing and acceptance criteria*. The initial three specimens shall be tested and if the average of the three impact test results is less than the specified minimum average value, or if one individual result is less than 70 % of the specified minimum average value, or if two results are less than the specified minimum average value, then three additional test pieces from the same sample shall be tested and the results added to those previously obtained and a new average value calculated.

The new average value shall not be less than the specified minimum average value. Not more than three of the total of six results shall be less than the specified minimum average value, nor more than two results less than 70 % of the specified minimum average value, and no individual result shall be less than 50 % of the specified minimum average value. If the results fail to comply with the above requirements, the procedure concerned shall be rejected. The cause of failure shall be established and depending on the cause either the procedure shall be modified without necessitating a new procedure test (see range of approval in BS EN 288-3) or a new procedure shall be established and approved by the Engineer.

Table 4 — Heat affected zone test requirements for notch ductility in transverse butt welds

Heat welding input	Specified minimum yield strength of parent plate	
	Under 400 N/mm²	400 N/mm² and over
Up to and including 5 kJ/mm	No test requirement	As given in **5.4.1.2**a), when specified by the Engineer
Over 5 kJ/mm	As given in **5.4.1.2**a), when specified by the Engineer	As given in **5.4.1.2**a)

5.4.2 ***Testing of welding for cast steel***

Non-destructive and destructive testing of welding shall comply with the requirements of BS 4570.

5.4.3 ***Testing of flame cut and sheared edges***

Where the hardness criteria of **4.3.3**a) or **4.3.3**d) are adopted, hardness testing shall be carried out on the edges concerned.

5.4.4 ***Stud shear connectors***

For each procedure trial, examination and testing shall be carried out on six specimens as follows.

a) Metallographic examination and hardness tests shall be carried out on macrosections prepared on a plane along the axis of the stud of three of the specimens. The weld shall be free from macroscopic defects visible to the naked eye. The hardness of the weld metal shall lie in the range 150 HV 30 to 350 HV 30 when tested in accordance with BS EN ISO 6507. The hardness of the HAZ in the stud and the flange shall not exceed 350 HV 30 as given in BS 427 where the applied principal tensile stress at the ultimate limit state in the flange is equal to or greater than 100 N/mm² or 400 HV 30 where the flange is in compression or the applied principal tensile stress at the ultimate limit state in the flange is less than 100 N/mm².

b) Each of the remaining three studs of the sample shall be bent to a lateral movement of the head of approximately half of the height of the stud and then bent straight again without failure of the weld.

5.5 Production tests

5.5.1 ***Destructive testing of welding for structural steel***

5.5.1.1 *Production test plates*

Unless otherwise specified by the Engineer, approximately one in five pairs of "run-off" plates for transverse butt welds in tension flanges and one in 10 pairs for other butt welds shall be production test plates. The combined size of each pair of production test plates shall be adequate for the number and size of specimens to be tested. The material quality of the "run-off" plates shall be the same as that of the plates to be welded. On completion of the welds the "run-off" production test plates shall not be removed until they have been marked in a manner, agreed by the Engineer, to identify them with the joints to which they are attached.

5.5.1.2 *Testing*

The following tests shall be carried out on the production test plates.

a) *Transverse tensile test.* One transverse tensile test comprising sufficient specimens to cover the full plate thickness shall be made in accordance with BS EN 895 and the tensile strength shall be not less than the corresponding specified minimum value for the parent metal.

If any specimen fails to meet the test requirement then a further test shall be made from the same production test plate. If any specimen from this further test fails to meet the test requirement then the joint shall be rejected.

b) *Bend test*. Bend tests shall be made in accordance with BS EN 910. For material less than 10 mm in thickness one transverse root bend test and one transverse face bend test shall be made. For material 10 mm in thickness and over, one side bend test comprising sufficient specimens to cover the full plate thickness shall be made. The diameter of the former and the angle of the bend used in the test shall comply with the requirements of BS EN 288-3. On completion of bending any defects in the tension surface of the test specimen shall be investigated and their cause established before the specimen is either accepted or rejected. Slight tearing at the edges of the test specimen shall not be a cause for rejection.

If any specimen fails to meet the test requirement then a further test shall be made from the same production test plate. If any specimen from this further test fails to meet the test requirement then the joint shall be rejected.

c) *Charpy V-notch impact test*. Charpy V-notch impact tests shall be made in accordance with BS EN 875 on weld metal in butt welds transverse to and carrying the main tension stress.

Additionally, where specified by the Engineer, Charpy V-notch impact tests shall be made on the fusion boundary region of the HAZ and shall comply with the requirements of **5.4.1.2**.

5.5.1.3 *Re-welding and re-testing*

In the event of failure to meet the test requirements of **5.5.1.1** and **5.5.1.2** the results shall be submitted to the Engineer who will determine whether the joints concerned and those represented by the tests may be accepted without additional work, or accepted subject to other satisfactory tests or additional work or rejected.

Rejected joints shall be cut out, rewelded and the tests repeated.

5.5.2 ***Non-destructive testing of welds in and attached to principal structural steelwork***

5.5.2.1 *General*

The methods and scope of inspection and acceptance criteria for weld discontinuities are only applicable to joints where the class requirement is other than B or C. All welds shall be inspected not less than 48 h after welding using the methods given in **5.5.2.2** and detailed procedures approved by the Engineer.

The extent of inspection shall be as indicated in **5.5.2.3** taking into account any minimum class requirement shown on the drawings. The position of all partial inspections shall be recorded.

The position and details of all discontinuities which are unacceptable according to **5.5.2.4** shall be recorded, and reported to the Engineer.

For the purposes of the inspection requirements of clause **5.5.2.3** a longitudinal weld is a weld the axis of which lies within 30° of the direction of stress fluctuation shown on the drawings. Welds at other orientations shall be deemed to be transverse welds.

Where the direction of stress fluctuation is not shown, the longitudinal direction shall be assumed to be parallel to the long axis of the member concerned. However, at intersections within 100 mm of a zone of connection between structural members or points of application of concentrated force all welds shall be treated as transverse. See Figure 1.

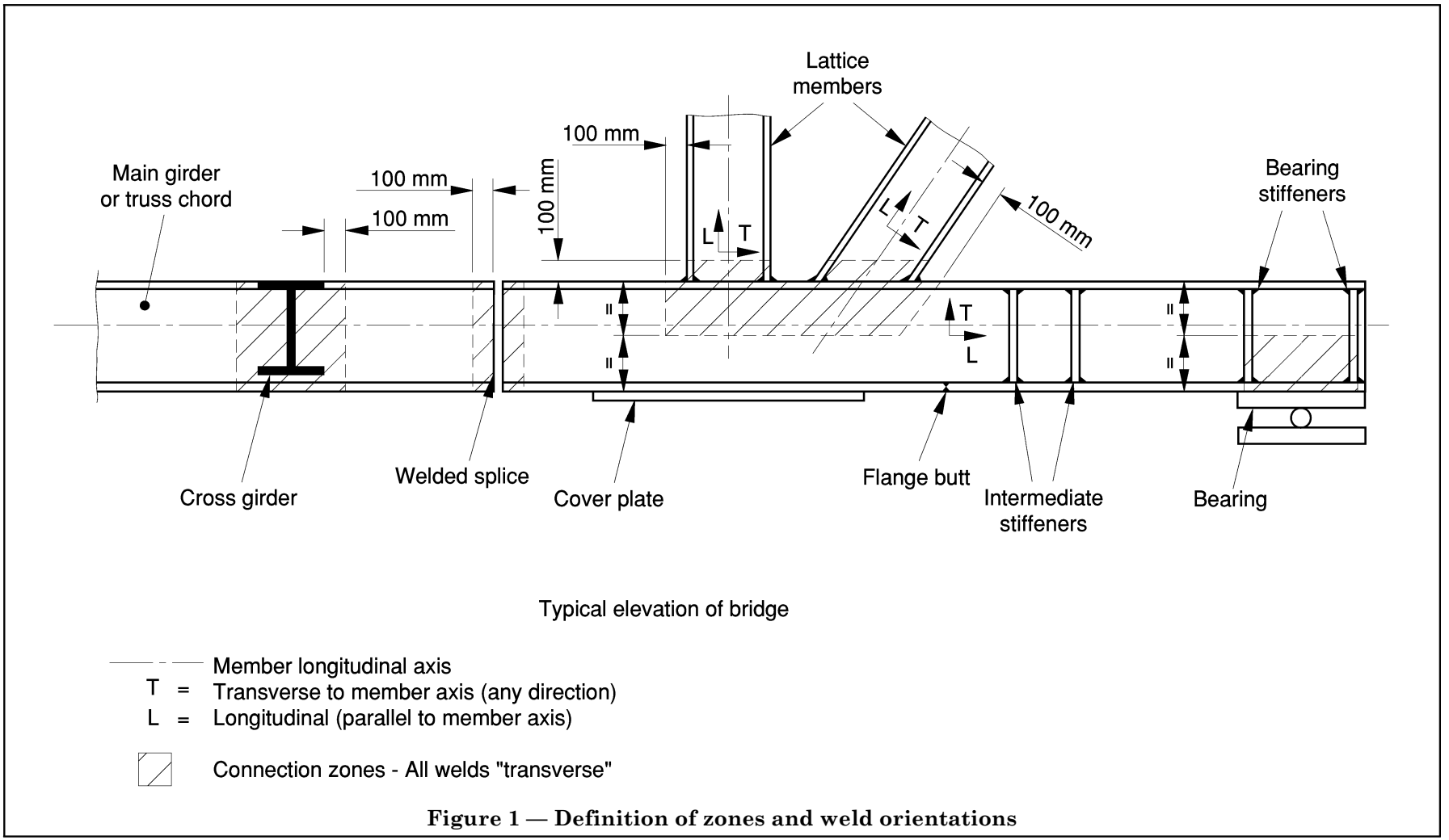


Figure 1 — Definition of zones and weld orientations

5.5.2.2 *Method of inspection*

5.5.2.2.1 *Surface inspection*

Visual inspection shall be carried out using the methods given in BS EN 970.

Magnetic particle inspection shall be carried out using the methods given in BS 6072.

5.5.2.2.2 *Sub-surface inspection*

Radiography shall be carried out in accordance with one of the techniques given in BS EN 1435.

Ultrasonic inspection shall be in accordance with the methods of BS 3923-1 and Table 5.

5.5.2.3 *Extent of inspection*

5.5.2.3.1 *Visual inspection*

100 % of all welds shall be visually inspected.

Table 5 — Examination levels to be used in the ultrasonic inspection of welds

Joint type	Examination level requirements with reference to BS 3923-1			
	Minimum class requirement			
	Class D	Class E	Class F	Not specified
Transverse in line butt joints	Special treatment	Examination level 2A (See note 1)	Examination level 2B (See note 1)	
Transverse tee, cruciform and corner joints	Not applicable		Examination level 3 (See note 2)	
Full penetration longitudinal butt joints	Examination level 3			
Longitudinal tee, cruciform and corner joints	Examination level 3			

NOTE 1 Scans for discontinuities transverse to the weld axis are not required.

NOTE 2 The primary purpose of these scans is the detection of lamellar tearing and toe cracking.

5.5.2.3.2 *Partial inspection*

After completion of the visual inspection specified in **5.5.2.3.1** and where less than 100 % inspection is specified in **5.5.2.3.3** and **5.5.2.3.4**, the particular lengths of joint to be inspected shall be agreed with the Engineer. In all cases the length of joint inspected shall be not less than 300 mm or for shorter joints the total length of the joint. Inspected lengths shall be spaced along the weld and include any lengths where visual inspection has indicated that internal quality is in doubt.

When unacceptable discontinuities are detected an additional equal length of the joint shall be examined on each side of the previously examined length.

Where discontinuities are detected within these additional lengths, 100 % of that weld shall be inspected. If no further unacceptable discontinuities are found then, subject to the satisfactory repair of those found, the joint shall be considered acceptable.

Where a non-conformity is attributed to a systematic deviation in workmanship, materials, equipment function, welding procedure or to a specific detail all other welds potentially affected shall be inspected.

5.5.2.3.3 *Magnetic particle inspection*

The extent of magnetic particle inspection shall be at least as follows:

a) 5 % of the length of each continuous weld;

b) 1 in 20 welds along intermittently welded longitudinal stiffener to plate joints when there are 3 or more stiffeners within the width of a fabricated panel between longitudinal plate splices;

c) 1 in 10 welds along all other intermittently welded joints;

d) a length of 25 mm at the end of any longitudinal attachment including terminations at cope holes;

e) 100 % of all transverse joints where either:

1) a minimum class requirement is shown on the drawings; or

2) the joint consists of a fillet welded attachment of length greater than 150 mm in the longitudinal direction;

f) areas from which temporary attachments have been removed.

NOTE Drawn arc welded studs need not be subjected to magnetic particle inspection.

5.5.2.3.4 *Ultrasonic inspection*

The extent of ultrasonic inspection shall be at least as follows:

a) 100 % of all transverse in line butt joints. This shall be reduced to 5 % of the length of each joint provided that there is no minimum class requirement shown on the drawings and the drawings specify that the design stresses in the joint at serviceability limit states:

1) are always compressive; or

2) are tensile but do not exceed 75 N/mm^2;

b) 100 % of all transverse, tee, corner or cruciform joints made with butt welds or fillet welds of leg length 12 mm, or greater and minimum required Class E or F;

NOTE 1 This may be reduced to 5 % of the length where no minimum class requirement is shown on the drawings.

c) 10 % of each 10 m length or part thereof of all in line longitudinal butt joints or 5 % of each 10 m length of fillet welds with leg lengths of 12 mm and greater.

Where specified by the Engineer, ultrasonic testing of support diaphragms or bearing stiffeners adjacent to welds, plates in box girder construction adjacent to corner welds, flange plates adjacent to web/flange welds, material at cruciform welds or other details shall be carried out after fabrication.

NOTE 2 Radiography may be used in cases of dispute to clarify the nature, sizes or extent of multiple internal flaws detected ultrasonically.

5.5.2.4 *Acceptance criteria*

5.5.2.4.1 *Visual and magnetic particle inspection*

The fillet weld profile shall be such that the minimum leg length shown on the drawings, and the corresponding throat dimension are maintained.

Undercut is not permitted:

a) within 25 mm of weld terminations, external corners, and member edges or ends; or

b) on transverse welds where a minimum class requirement is shown on the drawings.

In transverse welds where no minimum class requirement is shown on the drawings the depths of undercut, shrinkage grooves, and root concavity shall not exceed 0.5 mm. On longitudinal welds it shall not exceed 1 mm regardless of minimum class requirement.

Nowhere shall the average net section thickness of material over any length of 100 mm be less than 95 % of the nominal material thickness.

Butt weld reinforcement height shall not exceed 3 mm and weld overlap shall not be permitted. Excess penetration beads exceeding 1.5 mm in height shall not be permitted on single sided transverse butt welds and shall not exceed 3 mm on longitudinal butt welds.

NOTE 1 In all cases the bead should blend smoothly with the parent material.

Surface breaking cracks and other discontinuities shall not be permitted except for the following.

1) Surface breaking porosity up to 2 mm diameter in longitudinal welds and in transverse welds where there is no specific class requirement except:

i) within 6 mm of a longitudinal weld termination; or

ii) or within 3 mm of a transverse weld toe; or

iii) anywhere in a transverse weld with a specific class requirement when the size shall be limited to 1 mm diameter.

In no case shall the cumulative length of surface breaking porosity in any 100 mm exceed:

20 mm for longitudinal welds;

10 mm for transverse welds.

2) Specified unpenetrated regions at the weld root inherent in fillet and partial penetration butt welded tee, cruciform and corner joints.

Repair by grinding shall not reduce the average net section thickness of the material over any length of 100 mm to less than 95 % of the nominal material thickness. The direction of final grinding marks shall be parallel to the direction of stress fluctuation shown on the drawings. Where the latter is not shown it shall be taken as parallel to the long axis of the member. At transverse weld toes burr machining shall be used.

5.5.2.4.2 *Ultrasonic inspection*

Discontinuities identified as cracks, other than lamellar tearing permitted below, shall be rejected. Where porosity or slag lines are such as to impede reliable detection or evaluation of other discontinuities the joint shall be rejected.

Embedded discontinuities shall comply with the requirements of Table 6.

In the case of cruciform, tee and corner joints the maximum permitted lengths l and Σl may be doubled in the case of lamellar tears or laminations within the zone indicated in Figure 3.

Table 6 — Acceptance limits for embedded discontinuities in welds

Minimum class requirement (see note 1)	**Permissible limits** (mm) (for definitions of dimensions see Notation)			
	Σl max.	h max.	l max. (see notes 2, 3 and 4)	
			$H < 6$	$H \geq 6$
E	$10t$	3	5	10
F	$10t$	3	10	20
Not specified	$10t$	3	10	$10t$

Notation (see also Figure 2)

l is the length of a single discontinuity;

Σl is the sum of l over any length of 600 mm or the weld length whichever is the lesser;

h is the height of a single discontinuity measured in the thickness direction;

t is the thickness of the thinner plate, or the throat size in the case of a fillet weld;

L is the longitudinal distance between adjacent ends of discontinuities;

H is the clear distance between two discontinuities or between a discontinuity and the nearest surface, both measured in a through thickness direction.

NOTE 1 The minimum class requirement shall relate to the stresses normal to the plane containing the dimensions h and l.

NOTE 2 Where two or more adjacent discontinuities exist such that the spacing between them is $H < 6$ mm and $0 < L < 10$ mm, their individual lengths, l, shall not exceed the value for $H < 6$ mm. Where $H < 6$ mm and $L < 0$ (i.e. overlap) they shall not be permitted for a minimum class of E and, in the cases of F and not specified, when the length, l, of either discontinuity exceeds the maximum value given for classes E and F respectively. Only one discontinuity in that group shall be permitted to be within 6 mm of a free surface.

NOTE 3 Where the weld length is less than 600 mm, the permitted value of Σl shall be reduced in linear proportion.

NOTE 4 In the case of fillet or partial penetration butt welds, the root shall not be considered as an outer surface.

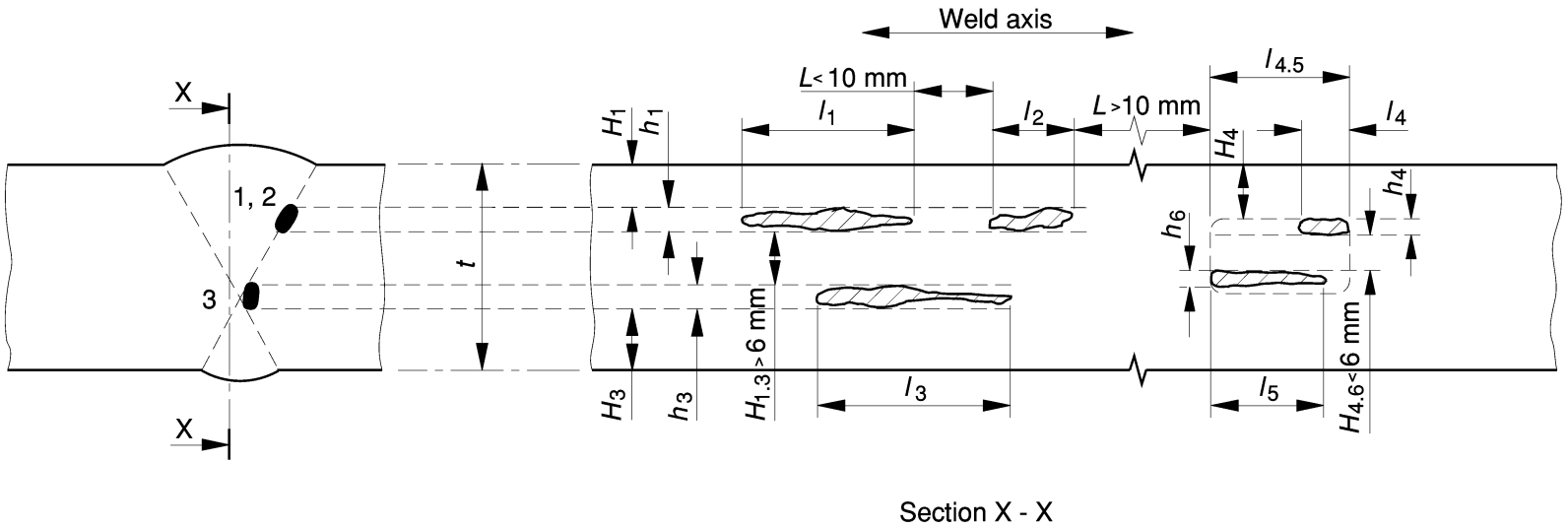
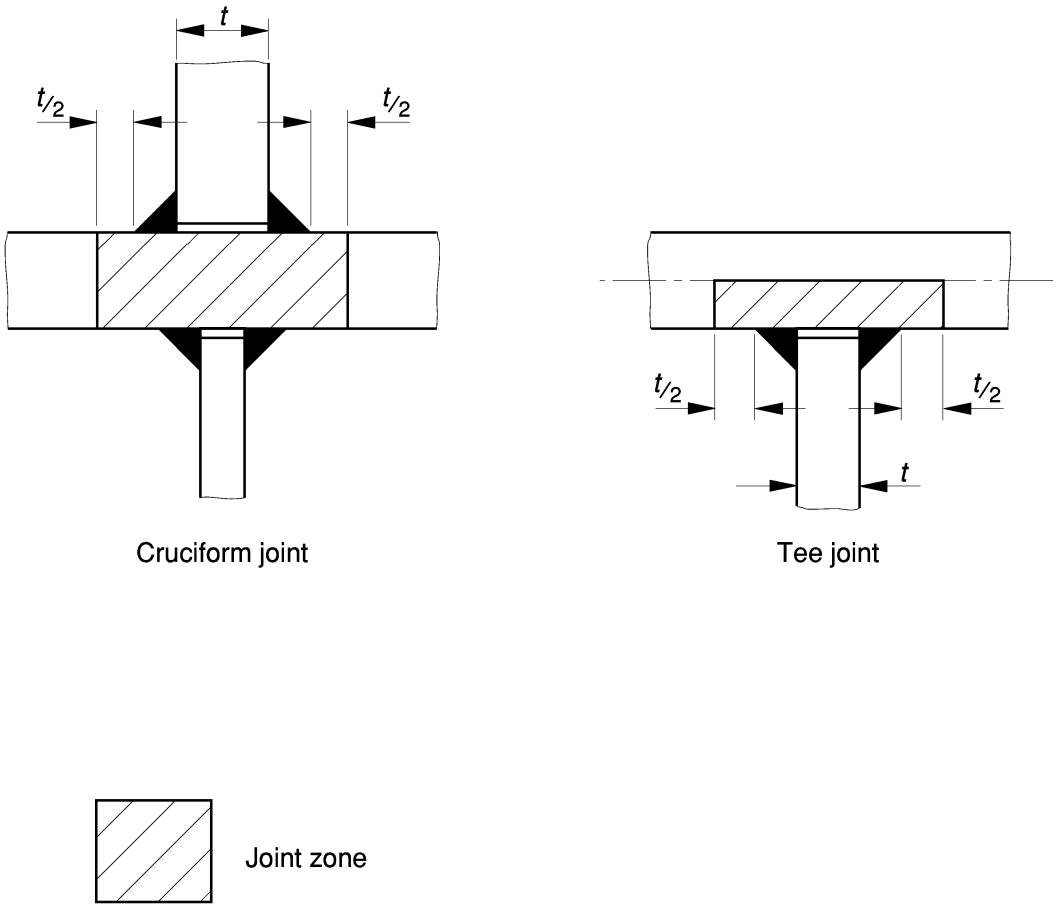


Figure 2 — Dimensions of discontinuities



NOTE See **3.1.4.2** and **5.5.2.4.2**.

Figure 3 — Zones in joints having to comply with Table 6

5.5.3 ***Testing of welding for cast steel***

The testing of welding for cast steel shall comply with the requirements of BS 4570.

5.5.4 ***Stud shear connectors***

Stud shear connectors shall be subjected to the following tests.

a) The fixing of studs after being welded in position shall be tested to the satisfaction of the Engineer by striking the side of the head of the stud with a 2 kg hammer.

b) Any stud selected by the Engineer shall be capable of being bent by striking the side of the head of the stud with a 6 kg hammer until its head is displaced laterally a distance of approximately 0.25 times the height of the stud from its original position. The stud weld shall not show any signs of cracking or lack of fusion. Satisfactory studs shall not be bent back again.

Studs whose welds have failed the tests given in a) and b) or which do not comply with the requirements of **4.7.4** shall be replaced according to a procedure to be agreed with the Engineer.

5.6 Checking of deviations in rolled and built-up sections

5.6.1 *Checking requirements*

Members/components of rolled and built-up sections shall be checked for compliance with the tolerances given in Table 8 in accordance with the requirements given in Table 7. Additionally all such members/components not subject to the checking requirements of Table 7 shall be visually examined for deviations in excess of the tolerances given in Table 8 and any such parts shall be quantitatively checked where necessary.

When inspecting members/components for compliance with tolerances, the checks for deviations shall be made over the full gauge length.

In making any checks, the scanning device shall be placed so that local surface irregularities do not influence the results.

The out-of-plane deviation of a plate panel at right angles to the surface shall be checked over the full area of the panel.

The checking of the out-of-straightness deviation at right angles to the plate surface for stiffeners may be checked either on the stiffener or on the plate attached to the stiffener on the line of the stiffener except in the vicinity of a site splice.

The out-of-straightness deviation parallel to the plate surface on the stiffener outstand shall be checked over the specified gauge length for the length of the stiffener.

The relative cross girder or cross frame deviation shall be checked over the middle third of the length of the cross girder or cross frame between each pair of webs. For cantilevers the relative deviation shall be checked at the end of the member.

The out-of-plane deviation of the web of a rolled beam or channel section shall be checked over a distance in the longitudinal direction equal to the depth of the section.

Member/component types 1 and 2 shall be checked at each site joint as follows.

Member/component type 1: checks shall be made for a distance of 1 m either side of the joint centre line or to the next boundary stiffener, whichever is the minimum distance.

Member/component type 2: checks shall be made over the length of the stiffened panel containing the joint.

Completed parts in which deviations have apparently increased since being inspected and checked shall be re-checked where required by the Engineer.

Table 7 — Tolerance checking requirements

Member/component type	Form of construction	Percentage of total number of members/components to be checked	Selection of members/components for checking
1, 2 and 5	Plate and box girders	5	50 % of the checks shall be made in critical areas specified by the Engineer. The remainder of the checks shall be made in areas selected at random by the Engineer
	Orthotropic decks	5	
	All other forms	10	
3, 4 and 6	All forms	100	

5.6.2 *Support during inspection*

Component stiffened plate panels shall be supported either on surfaces representing their intended fabricated shape or at their boundaries in a manner similar to that in the completed structure.

NOTE 1 Checks on member/component types 1, 2 and 5 (cross frames only), when these are incorporated in plate girders or box sections and checks on member/component types 3 and 6, may be done when the completed part is in either its horizontal or vertical position.

For member/component type 4 the checks shall be made with the web of the completed part in a vertical position.

NOTE 2 Girders capable of significant deflection under self-weight may also be supported at an intermediate position beneath an internal cross frame or vertical stiffener in such a way as to eliminate the deflection without inducing twist.

There shall be no external restraint or load on any completed part or component stiffened plate panel during inspection for and checking or measurement of deviations.

5.6.3 *Equipment*

Scanning devices capable of making the specified checks shall be calibrated with respect to a straight line datum so that the accuracy of recording is within ±0.5 mm.

5.6.4 *Gauge length*

The gauge lengths to be used shall be as given in Table 8 for each member/component type.

5.6.5 *Checking stages*

Checking for compliance with the tolerances given in Table 8 shall be carried out at the following stages:

a) for component stiffened plate panels and other completed parts, on completion of fabrication and before any subsequent operation of surface preparation, painting, lifting, transport or erection;

b) for member/component types 1 and 2 at site joints, on completion of the site joint;

c) for member/component type 5 (cross girders and cantilevers) and other parts in which deviations have apparently increased, on completion of site assembly.

5.6.6 *Non-compliance and rejection*

Where, on checking member/component types 1 and 2 for the deviations in respect of out-of-plane or out-of-straightness at right angles to the plate surface, the tolerances specified in Table 8 are exceeded, then the maximum deviation for the member/component shall be measured and recorded. In the case of member/component type 1 the maximum deviations in the plate panels adjoining the sides of the panel in question shall also be measured and recorded. For member/component type 2, the maximum deviation in respect of out-of-straightness at right angles to the plate surface for the stiffeners which are in line with the stiffener in question but in the adjacent bays shall also be measured and recorded.

Only the maximum deviation shall be measured and recorded for all other instances where the tolerances given in Table 8 are exceeded.

The recorded measurements shall be submitted to the Engineer who will determine whether the member/component may be accepted without rectification, with rectification, or rejected.

In the case of member/component types 1, 2, 5 and 6, where 10 % or more of the checks made on any one member/component type exceed the appropriate tolerances given in Table 8 then additional checks shall be made as directed by the Engineer.

5.7 Checking of alignment at joints

The alignment of plates at all bolted splice joints and welded butt joints shall be checked for compliance with the requirements of **4.2.4**.

5.8 Inspection and testing of rivets

Driven rivets, when struck sharply on the head with a rivet testing hammer, shall be free from movement and vibration. All loose rivets and rivets with cracked, badly formed or deficient heads, or with heads which are unduly eccentric with the shanks, shall be cut out and replaced. Re-cupping and caulking shall not be allowed. Where clearances are required, flattened rivet heads shall only be used with the approval of the Engineer.

5.9 Temporary erection at contractor's works

Where specified by the Engineer, steelwork shall be temporarily erected at the contractor's works to the Engineer's specification.

6 Handling, transport and erection

6.1 Handling and stacking

Fabricated parts shall be handled and stacked in such a way that permanent damage is not caused to the components. Means shall be provided to minimize damage to the protective treatment on the steelwork and any damage which does occur shall be made good.

6.2 Packing for transport

All work shall be protected from damage in transit. Particular care shall be taken to stiffen free ends and prevent permanent distortion and adequately protect all machined surfaces. All rivets, bolts, nuts, washers, screws, small plates and small articles generally shall be suitably packed and identified.

6.3 Erection

6.3.1 *General*

The bridge steelwork shall be erected, adjusted and completed in the required position to the lines and levels specified by the Engineer for the steelwork with appropriate allowances for permanent deformations during fabrication and erection.

6.3.2 *Site connections*

The structure shall be supported and site connections shall be securely held in position until the joints have been completed, to ensure accurate final alignment.

All connections shall be completed as soon as practicable after assembly.

6.3.3 *Service bolts*

Any connection to be riveted or bolted shall be secured in close contact by service bolts before the rivets are driven or before the connections are finally bolted.

6.3.4 *Drifts*

Drifts of the size specified in **4.12** may be used to bring the pieces accurately into place.

7 Supply, measurement and weighing

7.1 Computed weights

When payment is based on computed weights this shall be the nominal weight of the finished steelwork comprising plates, rolled sections, shear connectors, stiffeners, cleats, packs, splice plates and all fittings, without allowance for tolerances for rolling margin and other permissible deviations from standard weights or nominal dimensions, and excluding the weights of weld fillets, bolts, nuts, washers, rivet heads and protective coatings. No deductions shall be made for notches, cope holes, bolt and rivet holes, etc., which are less than 0.03 m^2 measured in plane.

The weight of rolled and cast steel and cast iron shall be determined from the dimensions shown on the drawing on the following basis:

a) rolled or cast steel, 7 850 kg/m^3;

b) cast iron, 7 210 kg/m^2;

c) 5 % addition for fillets and overruns for castings.

7.2 Weighbridge weights

When payment is based on weighbridge weight no deductions shall be made for the weight of weld fillets, bolts, nuts, washers, rivet heads and any protective coatings.

7.3 Numbers of site rivets, bolts and nuts and service bolts

Where erection at the site is not carried out by the steelwork supplier, he shall supply with the steelwork the full number of rivets, bolts, washers and nuts required to complete the work at the site. In addition, he shall, unless otherwise specified by the Engineer, supply the following spares:

a) for black bolts, nuts and washers, 5 % of the full number of each size required;

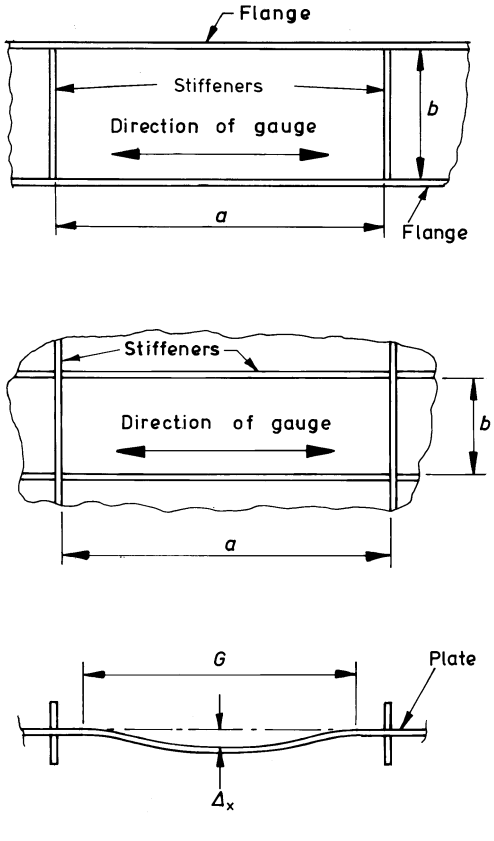
b) for close tolerance bolts, turned barrel bolts, high strength friction grip bolts, nuts and washers, 2.5 % of the full number of each size required;

c) for rivets, 10 % of the full number of each size required, when that number is 250 or less, together with 5 % of any excess over 250.

The steelwork supplier shall also supply service bolts, complete with nuts and washers, equal to 25 % of the net number of site rivets for all girder work and 10 % of the net number of site rivets for trough and plated floors. In the case of multiple spans the number of service bolts may be reduced by the Engineer.

In the case of site bolted connections, the contractor shall supply service bolts to the extent of 5 % of the number of close tolerance and barrel bolts.

Table 8 — Tolerances

Member/ component type	Description	Gauge length	Tolerance	Examples
1. Plate panels in webs of plate and box girders in stiffened compression flanges and in box columns				
a) $\frac{b}{t} > 25\sqrt{\frac{355}{\sigma_y}}$	Flatness at right angles to plate surface, measured parallel to the longer side in either direction	$G = a$ where $a < 2b$ $G = 2b$ where $a > 2b$	$\Delta_x = \frac{G}{165}\sqrt{\frac{\sigma_y}{355}}$ or 3 mm whichever is the greater (see note 4)	
b) $\frac{b}{t} \leq 25\sqrt{\frac{355}{\sigma_y}}$			No tolerance required unless otherwise specified by the Engineer	

where

a is the length of the longer side of a plate panel;

b is the length of the shorter side of a plate panel;

G is the gauge length;

t is the thickness of plate;

Δ_x is the maximum deviation from flatness within a specified gauge length;

σ_y is the specified yield stress of steel used (in N/mm²).

NOTE 1 The unit of measurement is millimetres.

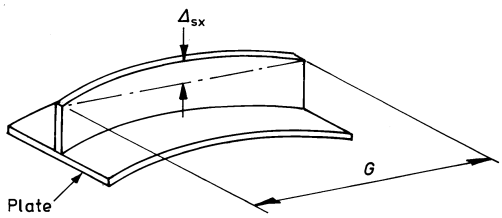
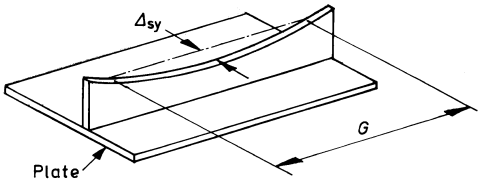
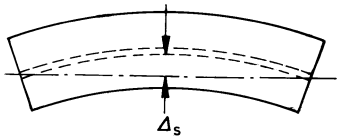
NOTE 2 Measurements should be taken to the nearest 1 mm and should be related to a sign convention as agreed with the Engineer.

NOTE 3 Calculated tolerances should be rounded to the next whole 1 mm.

NOTE 4 Any step at splices should be taken into account when checking and/or measuring deviations.

NOTE 5 Allowance for any intended curvature as shown in the examples should be made when checking and/or measuring deviations.

Table 8 — Tolerances *(continued)*

Member/ component type	Description	Gauge length	Tolerance	Examples
2. Longitudinal compression flange stiffeners in box girders, box columns and orthotropic decks. All web stiffeners in plate and box girders	a) Straightness at right angles to the plate surface in either direction	$G = L$	$\Delta_{sx} = \frac{G}{750}$ or 2 mm whichever is the greater	
	b) Straightness parallel to plate surface in either direction (not applicable to closed section stiffeners)	$G = 2b$ or L whichever is the lesser	$\Delta_{sy} = \frac{G}{375}\sqrt{\frac{\sigma_y}{355}}$ or 2 mm whichever is the greater	
3. Columns and struts	Maximum deviation from straightness including that of individual flanges in either direction	$G = L_s$ and L_F	$\Delta_s = \frac{G}{1\,000}$ or 3 mm whichever is the greater	

where

b is the length of the shorter side of a plate panel;

G is the gauge length;

L is the clear length of the stiffener between adjacent transverse stiffeners, cross frames, cantilevers or diaphragms;

L_F is the length of each fabricated piece;

L_s is the clear length of struts and columns;

Δ_s, Δ_{sx}, Δ_{sy} are the maximum deviations from straightness within a specified gauge length;

σ_y is the specified yield stress of steel used (in N/mm²).

NOTE 1 The unit of measurement is millimetres.

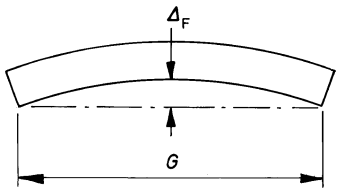
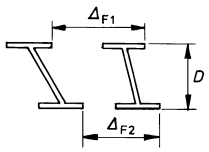
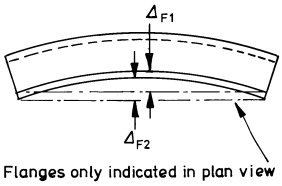
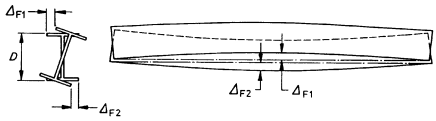
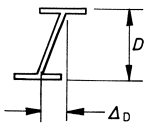
NOTE 2 Measurements should be taken to the nearest 1 mm and should be related to a sign convention as agreed with the Engineer.

NOTE 3 Calculated tolerances should be rounded to the next whole 1 mm.

NOTE4 Any step at splices should be taken into account when checking and/or measuring deviations.

NOTE5 Allowance for any intended curvature as shown in the examples should be made when checking and/or measuring deviations

Table 8 — Tolerances *(continued)*

Member/ component type	Description	Gauge length	Tolerance	Examples
4. Rolled or fabricated girders				
a) Including box sections	Straightness of individual flanges	$G = L_G$ and L_F	$\Delta_F = \frac{G}{1\,000}$ or 3 mm whichever is the greater	
b) Excluding box sections	Relative straightness of one flange with respect to the other for girders 750 mm and over in depth	$G = L_F$	$\Delta_F = \frac{G}{1\,000}$ or $\frac{D}{75}$ whichever is the lesser with a minimum of 3 mm	 $\Delta_F = \Delta_{F1} - \Delta_{F2}$ (at any one section)   $\Delta_F = \Delta_{F1} + \Delta_{F2}$ (at any one section)
	Verticality of web at supports	$G = D$	$\Delta_D = \frac{G}{300}$ or 3 mm whichever is the greater	

where

D is the depth of plate girder or rolled section;
G is the gauge length;
L_G is the length of girder in the completed structure;
L_F is the length of each fabricated piece;
Δ_D is the maximum deviation of girder from verticality at supports;
Δ_F, Δ_{F1}, Δ_{F2} are the maximum deviations from straightness within a specified gauge length.

NOTE 1 The unit of measurement is millimetres.

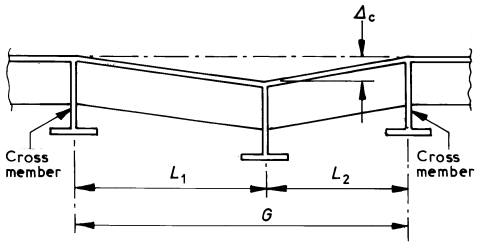
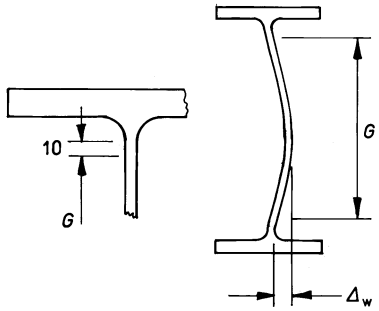
NOTE 2 Measurements should be taken to the nearest 1 mm and should be related to a sign convention as agreed with the Engineer.

NOTE 3 Calculated tolerances should be rounded to the next whole 1 mm.

NOTE 4 Any step at splices should be taken into account when checking and/or measuring deviations.

NOTE 5 Allowance for any intended curvature as shown in the examples should be made when checking and/or measuring deviations.

Table 8 — Tolerances *(concluded)*

Member/ component type	Description	Gauge length	Tolerance	Examples
5. Cross girders, cross frames and cantilevers in orthotropic decks or in compression flanges of box girders or on all sides of stiffened box columns	Levels between cross girder under consideration and the two adjacent cross girders in either direction	$G = L_1 + L_2$	$\Delta_c = \frac{G}{500}$ or 3 mm whichever is the greater	
6. Webs of rolled sections in the regions of the internal supports of continuous beams and elsewhere (as shown on the drawings)	Flatness at right angles to web plate surface measured over the gauge length in either direction	$G = W$	$\Delta_w = \frac{G}{165}\sqrt{\frac{\sigma_y}{355}}$ or 3 mm whichever is the greater	

where

G is the gauge length;

L_1 and L_2 are the distances between two adjacent cross girders, cross frames or cantilevers;

W is the depth of rolled section between fillets minus 20 mm;

Δ_c, Δ_w are the maximum deviations from flatness within a specified gauge length;

σ_y is the specified yield stress of steel used (in N/mm²).

NOTE 1 The unit of measurement is millimetres.

NOTE 2 Measurements should be taken to the nearest 1 mm and should be related to a sign convention as agreed with the Engineer.

NOTE 3 Calculated tolerances should be rounded to the next whole 1 mm.

NOTE 4 Any step at splices should be taken into account when checking and/or measuring deviations.

NOTE 5 Allowance for any intended curvature as shown in the examples should be made when checking and/or measuring deviations.

Annex A
Steel rivets

A.1 Material

A.1.1 *Requirements*

Rivets shall be manufactured from round bar material of grade S 275 according to national Annex NA of BS EN 10025, or of grade S 355JO, and also complying with the additional requirements given in **A.1.2**, **A.1.3**, **A.2** and **A.3**.

A.1.2 *Tensile test*

One tensile test shall be made from each cast for any quantity rolled up to 10 tonnes and another tensile test shall be made for each further 10 tonnes or part thereof, from that cast.

NOTE The test pieces may be full size as rolled.

A.1.3 *Additional tests*

A.1.3.1 *Grade S 275 bar*

The following additional tests shall be carried out on a grade S 275 bar.

a) *Sulfur print test.* A sulfur print test shall be taken from each cast used for round bars for the purpose of ensuring that sulfur segregates are not concentrated in the core. The stage in manufacture at which this test is made shall be at the option of the steelmaker.

b) *Dump test.* Short lengths equal to twice their diameter cut from the round bars shall, when cold, be compressed to half their length without fracture. One test per cast shall be taken.

A.1.3.2 *Grade S 355JO bar*

The following additional tests shall be carried out on a grade S 355JO bar.

a) *Cold bend test.* The test piece shall withstand without fracture being doubled over, either by pressure or by blows from a hammer, and closed flat.

Two cold bend tests shall be made from each cast for any quantity rolled up to 10 tonnes and another two cold bend tests shall be made for each further 10 tonnes or part thereof, from that cast.

b) *Hot compression test.* A test piece having a length equal to twice its diameter shall be cut from a bar and shall, without cracking or showing signs of fracture, withstand being heated to a forging temperature and hammered on end until the length has been reduced to one diameter.

One hot compression test shall be made from each cast for any quantity rolled up to 10 tonnes and another hot compression test shall be made for each further 10 tonnes or part thereof from that cast.

A.2 Tests on manufactured rivets

A.2.1 *Bend test*

The rivet shank shall be bent cold and hammered until the two parts of the shank touch, in the manner shown in Figure A.1, without fracture on the outside of the bend.

One bend test shall be made for each size in each batch of not more than 1 000 rivets.

A.2.2 *Flattening test*

The rivet head shall be flattened, while hot, in the manner shown in Figure A.2 until the diameter is 2.5 times the diameter of the shank. The edges shall not crack.

One flattening test shall be made for each size in each batch of not more than 1 000 rivets.

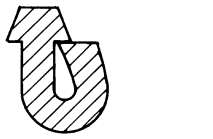


Figure A.1 — Rivet bend test

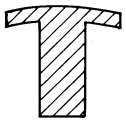


Figure A.2 — Rivet flattening test

A.2.3 ***Retests***

Should a rivet not fulfil the test requirements of **A.2.1** and **A.2.2**, two further rivets shall be selected and tested. Provided the results of both these further tests fulfil the test requirements, the batch represented shall be deemed to comply with the requirements of this standard.

A.2.4 ***Reheat treatment***

Notwithstanding the requirements of **A.2.1** and **A.2.2**, the manufacturer shall have the right to heat treat or reheat-treat any rivets including those already found not to fulfil the test requirements and resubmit them for testing.

A.3 Marking

Each bundle or package of rivets shall be clearly marked with the following information:

a) mild steel (MS) or high tensile steel (HT);

b) batch number;

c) type;

d) diameter;

e) length;

f) number of rivets.

Annex B
Guidance clauses

These clauses represent a standard of good practice and give guidance on the requirements of this part of this standard. The clause numbers and titles correspond to those given in the text.

3 Materials

3.1 Structural steels

Attention is drawn to the fact that it is sometimes the practice of rolling mills to correct rolling defects by repair welding without obtaining the specific approval of the Engineer. Where, because of fatigue or brittle fracture considerations, the Engineer requires material without such repair welding, these areas should be clearly specified.

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

The carbon equivalent value of steel is one of the factors affecting the need for preheat treatment (see BS 5135). For steels complying with the requirements of the standards designated in **3.1.1** this is important for the larger thicknesses and/or higher strength steels. The Engineer should consider specifying the maximum carbon equivalent value stated in the standards designated in **3.1.1** for such material.

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

Where the design is based on the use of steel other than that complying with the requirements of the standards designated in **3.1.1** the specification for that steel should be in accordance with the requirements of Part 3 of this British Standard. Where the design is based on the properties of steel complying with the requirements of the standards designated in **3.1.1** but some other steel is offered for construction, the performance requirements given in Table 1 of this standard should not be inferior to those of the particular grade of the standards designated in **3.1.1** envisaged in the design.

3.1.3 ***Notch toughness***

Selection of steel to satisfy notch toughness criteria is covered in Part 3 of this British Standard.

3.1.4 ***Laminar defects***

Attention is drawn to the possible detrimental effects of lamination in steel plates and sections. This clause deals with some situations vulnerable to this effect; the Engineer should clearly indicate any other regions in which tension stresses are to be transmitted in the through thickness direction of steel, or regions in which the presence of laminations could prejudice structural integrity.

Steel which is to be used in such regions should be ultrasonically tested by the methods described in BS 5996 to a grade specified in the contract.

Any material found to be defective due to laminations may still be used at the discretion of the Engineer.

Where the total weld throat exceeds 30 mm, the Engineer should consider specifying and using materials of proven through thickness ductility quality for cruciform joints, tee-joints and corner joints to avoid lamellar tearing.

The material used to form cruciform or tee-joints is required to match the acceptance criteria of the weld joining these parts together. It therefore may not be sufficient to order plate to BS 5996 (or the equivalent material quality standard for other structural forms) without inspecting the material adjacent to such weld positions to check that it conforms to these requirements.

Where the total weld throat exceeds 30 mm, the Engineer should consider specifying and using materials of proven through thickness ductility quality for cruciform joints, tee-joints and corner joints.

3.1.5 ***Marking***

The Engineer should specify the additional marking requirements. In determining the scope of marking requirements the Engineer should take into account the ease of identification of different materials by variations in sectional shape or dimensions.

3.9 Stainless steel

Suitable grades given in BS EN 10088 are: 1.4301, 1.4306, 1.4432, 1.4436, 1.4541 and 1.4550. Where external exposure to the environment is involved the molybdenum bearing grades 1.4432 and 1.4436 have advantages in improved resistance to pitting.

3.10.2 ***Malleable cast iron*** and **3.10.3** ***Spheroidal or nodular cast iron***

The Engineer should specify the appropriate grades of material given in BS EN 1562 and BS EN 1563, to meet the performance requirements.

4 Workmanship

Additional specification clauses may be required to cover workmanship for specific applications dealing with cast iron and stainless steel.

4.2 Fabrication tolerances

The tolerances specified in **4.2** are required to meet design criteria and are compatible with the design rules given in Part 3 of this standard.

4.2.2 ***Rolled and built-up sections***

For member/component type 1 given in Table 8 there is no specific out of flatness tolerance for plate panels with $b/t \leq 25\sqrt{\frac{355}{\sigma_y}}$ from design considerations.

For member/component type 6, webs should also be checked in the vicinity of concentrated loads of significant magnitude on an unstiffened section of the web. Such locations should be shown on the drawings by the Engineer.

4.2.3 ***Flatness of a machined bearing surface***

Where machined bearing surfaces are in excess of 0.5 m square the Engineer should specify the flatness tolerance following consideration of the practical and economic aspects.

4.3.3 ***Flame cutting and shearing***

Levels of hardness below 350 HV 30 may be necessary to permit adequate preparation of surfaces to receive certain metal spray coatings.

Where required the Engineer should specify the areas of preparation of flame cut edges to comply with the requirements of this clause when fatigue class B of Part 10 of this standard is required.

4.3.6 ***Contact surfaces for high strength friction grip bolted connections***

Attention is drawn to the fact that some materials for shims may have polished surfaces. In these circumstances roughening should be carried out to give appropriate friction.

4.7.1 ***Welding of structural steels***

Certain joint classifications given in Part 10 of this standard may require additional workmanship clauses. Reference should be made to Appendix H of Part 10:1980, as amended by amendment No. 1:1999, for these recommendations.

Deslagging of welds and treatment of weld spatter should be dealt with prior to the commencement of the protective treatment.

4.7.3 ***Welding, flame cutting and shearing procedure trials***

The Engineer should give consideration to the acceptance of results obtained from procedure trials undertaken previously on directly comparable material samples, joint configurations and welding procedures.

4.7.5 ***Repair of unacceptable weld discontinuities***

In the interests of avoiding delays on the shop floor, it is advisable for the fabricator to seek the Engineer's approval of proposed repair procedures prior to the commencement of fabrication.

4.10 Forging and **4.11 Tie rods**

Hot formed items should have the mechanical properties detailed in the specification provided that the steel is not heated above 1100 °C at any stage and that after hot forming it is cooled below the transformation temperature and then normalized. The alternative is to forge at the normalizing temperature.

5 Inspection and testing

5.2.1 ***General***

Where thickness tolerances are checked the measurements may be confined to positions around the edges of the plates as rolled but should be not less than 15 mm from the edges of the plates.

5.4.1.1 *Non-destructive and destructive testing*

For tests on butt joints complying with the requirements of BS EN 288-3 where, due to joint geometry, it is not possible to obtain specimens of the required length, one of the plates in the joint may be reorientated similarly to that shown in Figure B.1, Figure B.2 and Figure B.3 for Charpy V-notch impact tests.

The Engineer may use the hardness tests on procedure test macrosections to judge whether the weld metal overmatches the parent material in strength for the weld metal notch ductility relaxation to be permitted. In addition the HAZ hardness results should be used to judge the acceptability of the welding procedure in respect of heat input from preheat. For normal conditions of restraint and for weld metal hydrogen levels given in scales A and B of BS 5135:1984, a HAZ hardness level of 350 HV 30 maximum is appropriate; for weld metal hydrogen levels of scales C and D, a HAZ hardness level of 400 HV 30 maximum is acceptable.

5.4.1.2 *Weld metal and heat affected zone (HAZ) Charpy V-notch impact test requirements for tension areas*

The notch ductility requirements for weld metal are the same as those for the parent material given in Part 3 of this standard, apart from the relaxation for transverse butt welds with overmatching strength. The requirements do not apply to joints which will always be in compression. Areas of high shear should be checked for the level of principal tensile stress. A relaxation is permitted for areas of low tensile stress, to half the Charpy test energy requirement at minimum design temperature.

Notch ductility values achieved in the HAZs of structural steels depend on the type of steel and the welding procedure used. Where the steel is of a low alloy type, or is specially heat treated, for example, by quenching and tempering to achieve optimum properties, careful attention to welding procedures is necessary to maintain optimum properties in the HAZs. The use of special steel manufacturing and heat treatment methods, which require careful attention to heat inputs to avoid damaging the notch ductility, does not normally arise in steels with a specified minimum yield strength below 400 N/mm^2 and with heat inputs below 5 kJ/mm.

Quenched and tempered or special low alloy steels, beyond the scope of BS 5135 for pre-heating, require that special consideration be paid to welding procedures in order to obtain adequate notch ductility and freedom from risks of cracking. Steels below a specified minimum yield strength of 400 N/mm^2 require that special consideration be paid to notch ductility where high heat inputs are concerned which may cause excessive grain growth. Where multiple arc processes or vertical-up procedures are used, an assessment of the effective heat input is necessary to decide whether this total figure of 5 kJ/mm is exceeded or not. The effective heat input in such cases is controlled by a number of operational factors and procedure tests should normally be carried out, including HAZ Charpy V-notch tests, if the apparent heat input exceeds 5 kJ/mm. It is likely that some deterioration in notch ductility of the HAZ may occur compared to the parent material, and in critical cases it may be necessary to choose parent material values above the minimum to ensure that adequate properties are retained in the HAZ.

NOTE The term "heat input" is related to "arc energy" and is calculated from the welding current, voltage, travel speed and thermal efficiency factor of the welding process.

Steels complying with the requirements of the standards designated in **3.1.1**, up to and including grade S 355 strength levels, are considered to be carbon and carbon manganese steels where HAZ procedure tests are only required for the high heat input condition. Steel grades S 420 and S 460 as given in the standards designated in **3.1.1**, are considered to be in the category with specified minimum yield strength above 400 N/mm^2 and require special consideration.

Apart from the inherent scatter of Charpy tests on weld metal there is considerable variation depending upon the orientation of the specimen and position of the notch. It is generally found that the worst results are obtained for specimens notched at the centre line of the weld, where this coincides with the centre line of individual runs. With respect to the positioning of specimens within the thickness, there is again considerable variation and the worst results are usually obtained for specimens notched at the root area. Fracture mechanics and residual stress considerations suggest that critical defect sizes for fracture will be smaller in regions close to the surfaces. For double V preparations or similar the root area of the weld would normally be in the mid-thickness area with a somewhat greater tolerance for flaws. For asymmetric double V preparations specimens should be taken near to the surface containing the smaller preparation, whereas for symmetric double V preparations the specimens may be taken near to either surface. For single V or equivalent preparations the specimens should be taken near to the surface containing the root area where defect tolerance may be most critical.

Where in **5.4.1.2**e) the Charpy V-notch test results fail the acceptance criteria the Engineer may give consideration, as an alternative to cut-out and repair, to the use of stress-relief-post-weld heat treatment at the joint or to the results of additional critical non-destructive testing carried out if it confirms that the joints are free from any flaws of a critical nature for the toughness results obtained.

For Charpy V-notch tests on butt joints where, due to joint geometry, it is not possible to obtain specimens of the required length, one of the plates in the joint may be reorientated as indicated inFigure B.1, Figure B.2 and Figure B.3 in order to obtain specimens of the necessary length.

Charpy V-notch impact tests are not required on fillet welds.

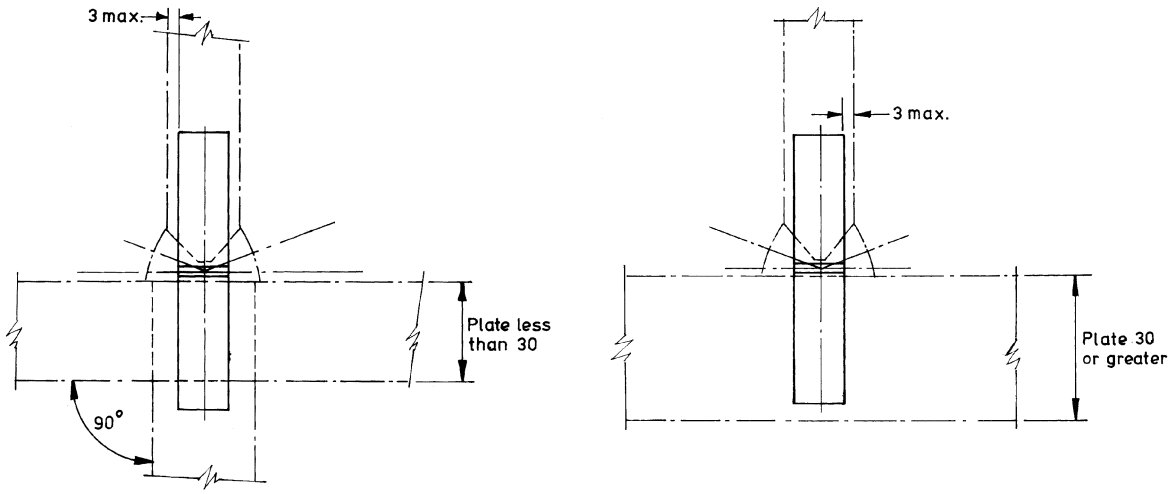
5.5.2 ***Non-destructive testing of welds in and attached to principal structural steelwork***

On the drawings of bridges designed to Part 10 of this standard, those areas where the achievement of a minimum fatigue strength is particularly important should have been delineated. This clause details the quality requirements necessary to achieve certain fatigue strengths in these critical areas to be met elsewhere.

Clauses requiring the attention of the Engineer

The following clauses contain points on which the decision of the Engineer is required and concerning which information is to be supplied when appropriate.

3.1.1	**4.1**	**5.3**	**6.3.1**	**7.3**
3.1.2	**4.2.3**	**5.5.1.1**		
3.1.3	**4.3.3**	**5.5.1.2**		
3.1.4.3	**4.3.6**	**5.5.1.3**		
3.1.5	**4.4**	**5.5.2.3.4**		
3.2	**4.4.4**	**5.5.4**		
3.3	**4.5.1**	**5.6.1**		
3.4.1	**4.5.3**	**5.6.6**		
3.4.3	**4.6**	**5.8**		
3.10.1	**4.7.1**	**5.9**		
	4.7.2			
	4.7.3			
	4.7.4			
	4.13			
	4.14			
	4.15			
	4.16			

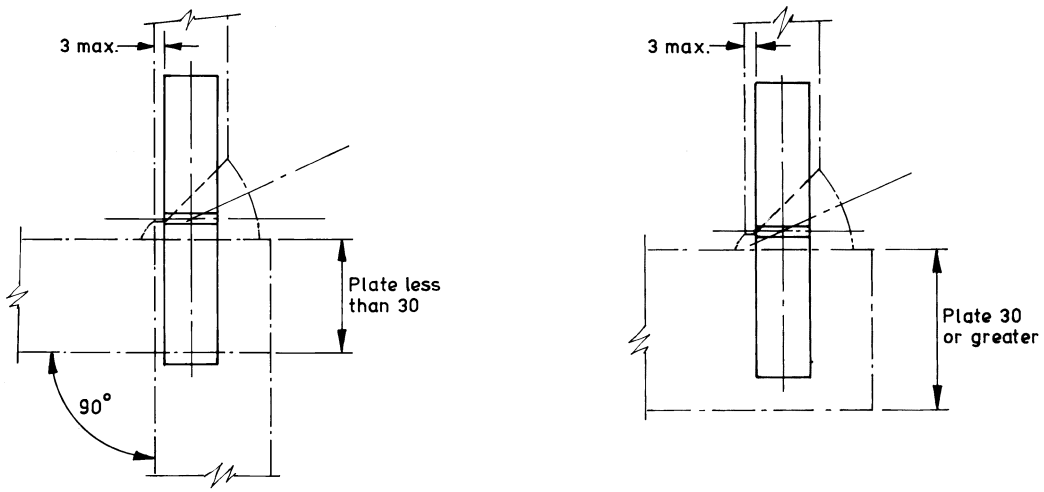


a) Orientation of test plates when plate thickness is less than 30 mm

b) Orientation of test plates when plate thickness is 30 mm or greater

All dimensions are in millimetres

Figure B.1 — Test specimens for Charpy V-notch impact tests, T-butt weld, showing reorientation of plate

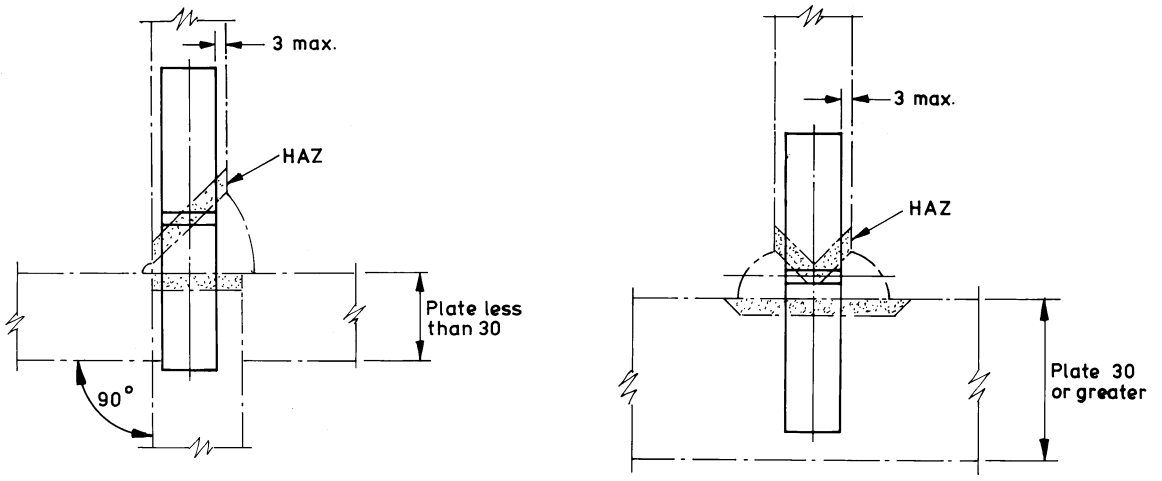


a) Orientation of test plates when plate thickness is less than 30 mm

b) Orientation of test plates when plate thickness is 30 mm or greater

All dimensions are in millimetres

Figure B.2 — Test specimens for Charpy V-notch impact tests, corner butt weld, showing reorientation of plate



a) Orientation of test plates when plate thickness is less than 30 mm

b) Orientation of test plates when plate thickness is 30 mm or greater

All dimensions are in millimetres

Figure B.3 — Test specimens for Charpy V-notch impact tests in the fusion boundary region of the HAZ, showing reorientation of plate

List of references (see clause 2)

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 29:1976, *Specification for carbon steel forgings above 150 mm ruling section.*

BS 427:1990, *Method for Vickers hardness test and verification of Vickers hardness testing machines.*

BS 970, *Specification for wrought steels for mechanical and allied engineering purposes.*

BS 970-1:1991, *General inspection and testing procedures and specific requirements for carbon, carbon manganese, alloy and stainless steels.*

BS 970-2:1988, *Requirements for steels for the manufacture of hot formed springs.*

BS 970-3:1991, *Bright bars for general engineering purposes.*

BS 970-4:1970, *Valve steels.*

BS 3100:1991, *Specification for steel castings for general engineering purposes.*

BS 3923, *Methods for ultrasonic examination of welds.*

BS 3923-1:1986, *Methods for manual examination of fusion welds in ferritic steels.*

BS 4190:1967, *Specification for ISO metric black hexagon, bolts, screws and nuts.*

BS 4320:1968, *Specification for metal washers for general engineering purposes — Metric series.*

BS 4395, *Specification for high strength friction grip bolts and associated nuts and washers for structural engineering.*

BS 4395-1:1969, *General grade.*

BS 4395-2:1969, *Higher grade bolts and nuts and general grade washers.*

BS 4570:1985, *Specification for fusion welding of steel castings.*

BS 4604, *Specification for the use of high-strength friction grip bolts in structural steelwork — Metric series.*

BS 4604-1:1970, *General grade.*

BS 4604-2:1970, *Higher grade (parallel shank).*

BS 4620:1970, *Specification for rivets for general engineering purposes.*

BS 4933:1973, *Specification for ISO metric black cup and countersunk head bolts and screws with hexagon nuts.*

BS 5135:1984, *Specification for arc welding of carbon and carbon manganese steels.*

BS 5400, *Steel, concrete and composite bridges.*

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