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ISO 10721-2

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Steel structures —

Part 2:
Fabrication and erection

Structures en acier —

Part 2: Fabrication et montage

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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10721-2 was prepared by Technical Committee ISO/TC 167, *Steel and aluminium structures*, Subcommittee SC 2, *Steel: Fabrication and erection*.

ISO 10721 consists of the following parts, under the general title *Steel structures*:

— *Part 1: Materials and design*

— *Part 2: Fabrication and erection*

Annexes A to D are for information only.

Introduction

This part of ISO 10721 establishes a common basis for drafting national standards for the fabrication and erection of steel structures, in order to ensure an adequate and consistent treatment of safety and serviceability compatible with ISO 10721-1. The specific and numerate requirements for the achievement of structures which are optimal with respect to the state of the economy, development and general values of a nation are given in the appropriate national standard.

NOTE Those concerned with a construction project may need to take into account the safety and health of the construction workers in accordance with national laws, regulations and practice. Thus, fabricators, clients, designers, constructors, employers, self-employed persons and employees may be concerned with this matter.

Steel structures —

Part 2:
Fabrication and erection

1 Scope

This part of ISO 10721 specifies the requirements for the fabrication, erection and inspection of structural steelwork in buildings designed in accordance with ISO 10721-1, including steelwork in composite steel and concrete structures.

This part of ISO 10721 is also applicable to bridges, off-shore and other civil engineering and related structures, but for such structures it may be necessary to consider other requirements.

NOTE For welded connections and for structures subject to fatigue, special considerations regarding scope and field of application are presented in 8.9 and 10.1 respectively of ISO 10721-1.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10721. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10721 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO R615, *Methods for determining the mechanical properties of the weld metal deposited by electrodes 3,15 mm or more in diameter.*

ISO 630, *Structural steel — Plates, wide flats, bars, sections and profiles.*

ISO 657 (all parts), *Dimensions of hot rolled steel sections.*

ISO 700, *Power sources for manual metal arc welding with covered electrodes and for the TIG process.*

ISO 1461, *Metallic coatings — Hot dip galvanized coatings on fabricated ferrous products — Requirements.*

ISO 2063, *Metallic coatings — Protection of iron and steel structures against corrosion — Metal spraying of zinc and aluminium.*

ISO 2081, *Metallic coatings — Electroplated coatings of zinc on iron or steel.*

ISO 2082, *Metallic coatings — Electroplated coatings of cadmium on iron or steel.*

ISO 2400, *Welds in steel — Reference block for the calibration of equipment for ultrasonic examination.*

ISO 2553, *Welded, brazed and soldered joints — Symbolic representation on drawings.*

ISO 3690, *Welding — Determination of hydrogen in deposited weld metal arising from the use of covered electrodes for welding mild and low alloy steels.*

ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers.*

ISO 7415, *Plain washers for high-strength and structural bolting, hardened and tempered.*

ISO 7963, *Welds in steel — Calibration block No. 2 for ultrasonic examination of welds.*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.*

ISO 8501-2, *Preparation of steel substrates before the application of paints and related products — Visual assessment of surface cleanliness — Part 2: Preparation grades of previously coated steel substrates after localized removal of previous coatings.*

ISO 8503-1, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces.*

ISO 8503-2, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel — Comparator procedure.*

ISO 9000 (all parts), *Quality management and quality assurance standards.*

ISO 9002, *Quality systems — Model for quality assurance in production and installation.*

ISO 9606-1, *Approval testing of welders — Fusion welding — Part 1: Steels.*

ISO 9692, *Metal-arc welding with covered electrode, gas-shielded metal-arc welding and gas welding — Joint preparations for steel.*

ISO 9956-1, *Specification and approval of welding procedures for metallic materials — Part 1: General rules for fusion welding.*

ISO 9956-2, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedure specification for arc welding.*

ISO 9956-3, *Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for the arc welding of steels.*

ISO 10721-1:1997, *Steel structures — Part 1: Materials and design*.

ISO 12944-4, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 4: Types of surface and surface preparation.*

ISO 14713, *Protection against corrosion of iron and steel in structures — Zinc and aluminium coatings guidelines.*

3 Materials

All materials should comply with the requirements of 6.3 of ISO 10721-1:1997.

For steels not complying with 6.3 of ISO 10721-1:1997, other requirements may be necessary.

Where no suitable International Standard exists, reference shall be made to appropriate national standards, certification schemes and agreements.

Unless stated otherwise, the national standards to be adopted are those of the country in which the structure is to be built.

Where no standards exist, the proprietary manufacturer's recommendations shall be adopted.

4 Fabrication workmanship

4.1 Material identification

The fabricator shall demonstrate the means used to effectively identify steel materials prior to fabrication and assembly of members. Hard stamping may be used except where otherwise specified by the designer, such as for elements subject to sudden impact or fatigue criteria or in regions where plastic hinges may occur.

4.2 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 relevant steel standard.

For cold bending of plates and flats, the internal radius of bends shall be within tolerances given in the design documents and shall not be less than the bend testing radius specified for the material thickness in the relevant steel standard.

For hot bending, the temperature, timing and cooling rate shall be appropriate to the particular type of steel. Bending in the blue heat range (290 °C to 380 °C) shall be avoided.

4.3 Straightening and flattening

Straightening and flattening shall be carried out by the application of heat or by the slow application of mechanical pressure; hammering is not permitted.

When straightening and flattening by the application of localized heat, the recommendations of clause B.4 in annex B should be followed.

4.4 Forging

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

4.5 Preparation of edges, ends and surfaces

4.5.1 General

Cutting shall be by sawing, shearing and machine thermal or laser cutting. Unguided flame cutting shall only be used for notching or the completion of the formation of slotted holes. Re-entrant corners shall be rounded by grinding and be free of overcutting.

4.5.2 Preparation of material

The preparation of the material shall be in accordance with the following requirements:

a) parent metal surfaces within 25 mm of the weld shall be smooth, uniform and free from cracks, loose or thick scale and other contaminants which would adversely affect the strength or quality of the weld;

b) where small notches or irregularities in gas-cut edges occur on otherwise satisfactory surfaces, they shall be removed by grinding or machining to a smooth profile.

   Notches in excess of 5 mm in depth or other discontinuities considered unacceptable shall be repaired by welding to an approved welding procedure. Subsequently, they shall be ground smooth and flush with the adjacent surface to produce an acceptable finish;

c) re-entrant corners shall be filleted to a radius of not less than 10 mm;

NOTE A re-entrant corner is a corner in which the open angle between the cut faces is less than 180°.

d) methods other than those given in 4.5 may be used for joint preparation, back-gouging or for the removal of unacceptable material except that thermal gouging shall not be used on quenched and tempered steels;

e) edges of built-up beam and girder webs shall be cut to the prescribed camber with suitable allowance for shrinkage due to cutting and welding. Deviations from the specified camber tolerance may be corrected by the use of an appropriate heating procedure;

f) steel surfaces shall:

1) **on rolled surfaces**, be no worse than Grade C in accordance with ISO 8501-1 and be free from surface defects in accordance with ISO 630,

2) **on cut surfaces**, have a suitable surface roughness and be free from sharp arrises which prevent the attainment of the surface conditions required for the painting system specified.

4.5.3 Flame cutting and shearing

Flame cutting and shearing shall be permitted for elements subject to consideration of the following:

a) where a fatigue quality is specified (see D.5.2 in annex D);

b) the cut edge is completely incorporated in the weld;

c) when specified, the maximum hardness of the cut edge does not exceed the levels given in the appropriate national standard;

d) the roughness of the cut edge does not exceed the value specified in the appropriate national standard.

4.5.4 Machining butted joints

Joint surfaces dependent on contact for the transmission of load shall be within the tolerances specified (see 8.6). No machining need be carried out on a bearing face which is to be grouted directly to a foundation.

Compression joints which depend on contact bearing shall have the bearing surfaces of individual fabricated pieces prepared to a common plane by sawing or machining.

4.5.5 Contact surfaces for slip-resistant connections

All contact surfaces shall, at the time of assembly, be as specified and free of any contaminant.

When the joint is assembled, the contact surfaces shall be free from dust, oil, paint or other deleterious materials, except for a planned slip-resistant coating. Spots of oil which cannot be removed by flame cleaning without leaving harmful residues shall be removed by suitable chemical means. If rust forms on the contact surfaces before they have been assembled, it will be sufficient to remove any thin films of rust or other loose material by brushing with a steel brush. During this process the roughened surface shall not be damaged or made smooth.

4.6 Holes for bolts and pins

4.6.1 Forming holes

Round holes for bolts shall be formed either by drilling or punching. Slotted holes shall be either punched in one operation or incrementally punched, or formed by drilling or punching two holes and completing by hand flame cutting. Countersinking shall be carried out by drilling. All holes shall be free from significant burrs.

Where holes are drilled in one operation through parts clamped together which would not otherwise be separated after drilling, they need not be separated to remove the burrs.

Holes through more than one plate should be punched in the same direction. Punching is allowed for a material up to 25 mm in thickness provided that the hole diameter is not less than the thickness of the material, and distortion of the hole is within 10 % of its specified diameter.

Anchor bolt holes in baseplates may be formed by thermal cutting.

Holes in elements subject to fatigue, or where specified, shall either be drilled or subpunched 2 mm undersize in diameter for preloaded bolts and 4 mm undersize for ordinary bolts and reamed.

4.6.2 Holes for general purpose and structural bolts

Except as permitted by 4.6.3, the diameter of the hole shall not exceed the nominal diameter of the bolt by more than:

a) 1 mm for bolts up to and including 14 mm in diameter;

b) 2 mm for bolts over 14 mm but less than 27 mm in diameter;

c) 3 mm for bolts 27 mm in diameter and larger.

4.6.3 Oversize and slotted holes

In accordance with A.8.8.2.2 in ISO 10721-1:1997, the hole dimensions given in Table 1 should apply.

In the case of oversize holes, greater attention shall be taken to ensure resistance to shear and tension when applicable.

4.6.4 Holes for pins

Pin holes shall be bored smooth, straight and true to gauge and at right angles to the axis of the member. Boring shall be undertaken only after the member is finally bolted or welded, unless otherwise permitted.

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.

Table 1 — Dimensions for oversize and slotted holes

Hole type	Hole dimension for bolt diameter d of		
	⩾ 16 mm and ⩽ 22 mm	**24 mm**	**⩾ 27 mm**
a) Oversize			
Maximum dia.	d + 4 mm	d + 6 mm	d + 8 mm
b) Short slotted			
Width	d + 2 mm	26 mm	d + 3 mm
Length (maximum)	d + 6 mm	32 mm	d + 10 mm
c) Long slotted			
Width	d + 2 mm	26 mm	d + 3 mm
Length (maximum)	2,5 d	60 mm	2,5 d

4.7 Bolts, nuts and washers

4.7.1 General purpose and non-preloaded structural bolts

The connected parts shall be firmly drawn together. All bolted splices shall be provided with steel packing plates in order to ensure that the total remaining step between adjacent plates does not exceed 2 mm.

The tip of the bolt shall be flush with or outside the face of the nut when installed. The thread may be included in the shear plane.

4.7.2 Countersunk bolts

Countersunk bolts shall comply with the requirements of the appropriate national standard.

4.7.3 Preloaded structural bolts

The tip of the bolt shall be flush with or outside the face of the nut when installed. The thread is permitted to be included in the shear plane unless otherwise stated.

4.7.4 Washers

4.7.4.1 Washers for preloaded bolts

Hardened washers for preloaded high-strength bolts shall be in accordance with the requirements of ISO 7415 as follows:

a) when bolts with a nominal f_u greater than 830 N/mm^2 and a diameter greater than 27 mm are used, hardened washers at least 8 mm in thickness shall be used;

b) when preloaded bolts are to be installed in an oversize hole or in a short slotted hole in an outer ply, a hardened washer shall be used. In outer plies of a joint for long slotted holes, structural plate washers or continuous bars at least 8 mm thick with standard holes shall be used to completely cover the slot;

c) when the inspection or installation procedure involves the use of a calibrated wrench or torque spanner, a hardened washer shall be used under the turned element.

In all joints using material having a nominal f_y less than 280 N/mm^2 and bolts having a nominal f_u greater than 830 N/mm^2, hardened washers shall be used;

d) to compensate for the lack of parallelism for bolts with an f_u greater than 830 N/mm^2, where the outer face of the bolted parts has a slope greater than 1:20 with respect to a plane normal to the bolt axis, a tapered washer shall be used.

4.7.4.2 Washers for ordinary bolts

a) When the nut would otherwise bind on the thread run-out, a washer shall be used.

b) A suitable washer shall be used under the head and nut when assembling components with oversize or slotted holes.

c) Washers shall be used under the bolt head and nut when used on metal-sprayed or galvanized steelwork.

d) Washers shall be used under the turned element when the surface is painted.

4.7.5 Nuts

4.7.5.1 Non-preloaded structural bolts

Nuts on non-preloaded structural bolts and ordinary bolts shall be tightened to an amount corresponding to the full effort of using a hand wrench. When so specified, nuts shall be prevented from working loose by the use of lock washers, lock nuts, jam nuts, defacing of the threads, welding or other methods approved by the designer.

4.7.5.2 Preloaded structural bolts

Nuts on preloaded structural bolts shall be installed in accordance with 4.7.7.

4.7.6 Galvanized bolts, nuts and washers

When specified, bolts, nuts and washers shall be galvanized with suitable quality control to avoid mismatch of nut and bolt threads. In the case of bolts with f_u minimum greater than 830 N/mm^2 and for all washers, suitable measures shall also be taken to avoid hydrogen embrittlement. Bolts of property class 12.9 should not be galvanized. In all cases, when bolts are installed in a connection they shall:

a) have three to five threads in the grip;

b) be capable of producing a tensile-type fracture of the bolt; and

c) be capable of rotating one full turn from snug before failure when properly lubricated.

4.7.7 Installation of preloaded structural bolts

Preloaded structural bolts shall be tightened as follows. However if necessary tightening may be undertaken by turning the bolt while holding the nut against rotation.

The permitted methods of tightening are:

a) turn-of-nut tightening;

After aligning the holes of the joint, the bolts shall be placed and brought to a “snug-tight” condition to ensure that the parts of the joint are brought into firm contact with one another. “Snug-tight” is defined as the tightness attained by full effort of using a hand wrench or by a few impacts of an impact wrench. Following the initial snugging operation, bolts shall be placed in any remaining holes and brought to snug-tightness. Re-snugging of bolts may be necessary in large joints. When all bolts are snug-tight, each bolt in the joint shall then be additionally tightened by the applicable amount of nut rotation given in Table 2. Tightening should proceed systematically from the most rigid part of the joint to its free edges.

Table 2 — Nut rotation from snug-tight condition

Bolt length [a]	Turn	Tolerance mm
⩽ 4 bolt diameters	1/3	± 30°
> 4 bolt diameters and ⩽ 8 bolt diameters or 200 mm	1/2	± 30°
> 8 bolt diameters or 200 mm	2/3	± 45°

[a] Bolt length is measured from underside of head to expected location of outer face of nut.

b) direct tension indicator;

Tightening of bolts using direct tension indicator devices is permitted provided the suitability of the device can be demonstrated by testing a representative sample of not less than three indicator devices for each diameter and grade of fastener in a calibration device capable of indicating bolt tension. The test assembly shall include flat hardened washers, if required in the actual connection, arranged similar to those in the actual connections to be tensioned. The calibration test shall demonstrate that the device indicates a tension not less than 5 % greater than that required by 8.8.2.3 of ISO 10721-1:1997.

c) any other method that can be demonstrated to meet the requirements of 8.8.2.3 of ISO 10721-1:1997.

Manufacturers' installation procedures shall be followed for installation of bolts in the calibration device and in all connections. Special attention shall be given to proper installation of flat hardened washers when load-indicating devices are used with bolts installed in oversize or slotted holes and when the load-indicating devices are used under the turned element. When the direct tension indicator involves an irreversible mechanism such as yielding or fracture of an element, bolts shall be installed in all holes of the connection and brought to snug-tight condition. All fasteners shall then be fully tightened, progressing systematically from the most rigid part of the connection to the free edges in a manner that will minimize relaxation of previously tightened fasteners prior to final twist-off or yielding of the control or indicator element of the individual devices. In some cases, proper tensioning of the bolts may require more than a single cycle of systematic tightening.

4.7.8 Reuse of bolts

Bolts with a nominal f_u greater than 830 N/mm^2 and galvanized bolts shall not be reused. Other bolts may be reused, provided f_u is not greater than 830 N/mm^2, if approved by the designer. Retightening previously partially tightened bolts which may have been loosened by the tightening of adjacent bolts shall not be considered as reuse.

4.7.9 Pins

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 smaller diameter and protection for the thread shall be provided.

4.8 Welding

4.8.1 General requirements

4.8.1.1 Welding processes

The welding process shall be selected from the following:

a) shielded metal arc (111);

b) gas metal arc (131, 135);

c) flux-cored arc (114, 136, 137);

d) submerged arc (121);

e) stud welding (781, 782).

NOTE Parentheses indicate process reference according to ISO 4063.

Any welding process not listed above but which gives equivalent results to those specified herein is not necessarily precluded. Such processes are acceptable when allowed by appropriate national standards, the welding procedures have been qualified as required by those standards, and use of the process is acceptable to the responsible authority.

Power sources for manual metal arc and TIG welding shall be in accordance with ISO 700. For other processes, the power sources shall be in accordance with appropriate national standards.

4.8.1.2 Filler metals

Electrodes, electrode-gas and electrode-flux combinations shall be as specified in the appropriate International Standards or appropriate national standards.

Where filler metal, electrode-gas or electrode-flux combinations are to be used which are not covered in the requirements of the appropriate International Standard, they shall be permitted provided they are in accordance with the approved welding procedures. The extent of the validity of such qualification shall be limited to the steel, the type of weld and the essential variables used in procedure qualification.

Methods for determining the mechanical properties of the weld metal from electrodes 3,15 mm or more in diameter shall be in accordance with ISO R615. For other electrodes, appropriate national standards may be used.

Hydrogen content of covered electrodes shall be determined in accordance with ISO 3690.

4.8.1.3 Weld symbols on drawings

Weld types, sizes and lengths shall be designated on the drawing in accordance with ISO 2553.

4.8.2 Workmanship

4.8.2.1 General welding requirements

Where the contract requires the use of approved welding procedures, these shall be approved in accordance with ISO 9956-1, ISO 9956-2 and ISO 9956-3 or appropriate national standards. For guidance on factors to be considered, see ISO 3088.

Where the contract requires the use of approved welders, they shall be approved to ISO 9606-1.

Welders and the associated weld joint shall be adequately protected against the direct effect of wind, rain and snow and other elements that could prevent acceptable results.

Welding shall not be undertaken when the steel temperature is lower than specified in accordance with the national standard, except with the express consent of the responsible authority.

This shall also apply to stud welding. However, if required in accordance with appropriate national standards, stud welding, when done below 0 °C, shall be permitted only if an additional number of studs beyond that normally required is successfully tested (refer to ISO 10721-1).

The sizes and lengths of welds shall be not less than those specified by design requirements and detail drawings, nor shall they be in excess of the requirements beyond the tolerances prescribed by national acceptance standards without approval. The location of welds shall not be changed without reference to the designer.

Depending upon the carbon equivalent of the steels, the combined thicknesses and the hydrogen level of the welding consumables, it may be necessary to preheat the steel before welding (refer to EN 1011-1 and EN 1011-2). In order to confirm preheat requirements, it may be necessary to carry out a welding procedure test in accordance with ISO 9956-1, ISO 9956-2 and ISO 9956-3.

Back-gouging shall produce a contour of a single U-groove with its fusion faces readily accessible for welding and its depth adequate to ensure penetration into the previously deposited weld metal.

4.8.2.2 Storage and conditioning of electrodes

After welding consumables have been removed from their original packages, they shall be protected or stored in accordance with the requirements of the appropriate national standard. Where the latter is unavailable, the manufacturer's recommendations shall be adhered to.

4.8.2.3 Assembly and fit-up tolerances

4.8.2.3.1 General

Joint preparation and fit-up dimensions for steels under this part of ISO 10721 shall be selected so as not to exceed the appropriate geometrical tolerances in ISO 9692.

4.8.2.3.2 Fillet-welded joint

The parts to be joined by fillet welds shall be brought into as close a contact as practicable. Where an occasional non-uniformity in the fit-up occurs, the local gap as related to the total length of the parts in the joint shall not exceed:

a) 2 mm for joints of maximum 600 mm in length;

b) 3 mm for joints over 600 mm in length and maximum 3 m in length;

c) 5 mm for joints over 3 m in length.

For parts 75 mm and greater in thickness, the gap shall not exceed 8 mm. However, for any gap greater than 3 mm, a sealing weld, with suitable backing material, shall be used to prevent melt-through and the final weld shall attain the required throat size.

In all cases where there is a local separation of 2 mm or greater over more than 10 % of the weld length, the leg of the fillet weld shall be increased to ensure that the design throat is maintained.

NOTE Backing to prevent burn-through may be of flux, glass tape, iron powder, or similar material, or it may be provided by means of root passes deposited by basic electrodes or other low hydrogen arc welding processes.

4.8.2.3.3 Lap joints

The separation between surfaces of lap joints shall not exceed 2 mm. The use of filler packs is prohibited unless otherwise specified.

4.8.2.3.4 Partial joint penetration groove (butt) welds

Except for bearing joints which must be in contact, the parts to be joined by partial penetration welds having joint preparation parallel to the length of the member shall be brought into as close contact as practicable. The gap between parts shall not exceed 5 mm except in cases involving rolled shapes or plates 75 mm or greater in thickness when a maximum gap of 8 mm is acceptable. If, after straightening and assembly, the gap is greater than 3 mm, a sealing weld or backing material shall be used and the final weld shall attain the required throat size.

4.8.2.3.5 Full joint penetration groove (butt) welds

Parts to be joined by groove (butt) welds shall be carefully aligned. An offset not exceeding 10 % of the thickness of the thinner part joined, but in no case more than 3 mm, shall be permitted as a departure from the theoretical alignment. Measurement of offset shall be based upon the centreline of parts unless otherwise shown on the drawing.

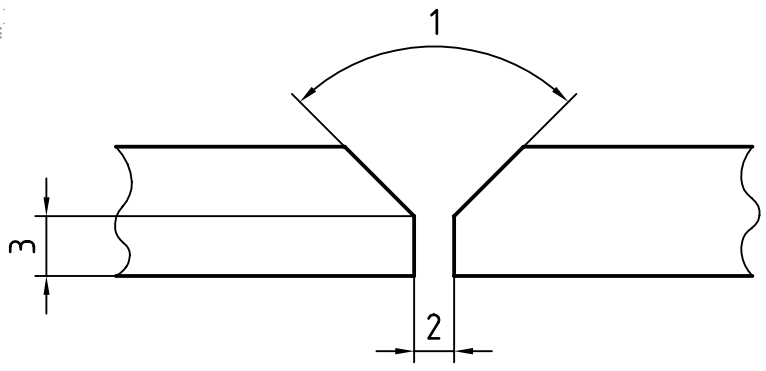
Where the material thicknesses differ by more than 3 mm the thicker material shall be prepared with a slope not exceeding 1 in 2,5.

4.8.2.3.6 Workmanship tolerances

The tolerances for groove (butt) joints are given in Table 3.

Table 3 — Workmanship tolerances for groove (butt) welds

Item	Root not gouged	Root gouged
Root face	± 2 mm	Not limited
Root gap		
Without steel backing	± 2 mm	+ 2 mm – 3 mm
With steel backing	+ 6 mm – 2 mm	Not applicable Not applicable
Groove angle of joint preparation	+ 10° – 5°	+ 10° – 5°



Key

1 Groove angle of preparation
2 Root gap
3 Root face

Figure 1 — Groove angle of groove (butt) joint preparation

Root gaps in excess of those given in Table 3 but not more than twice the thickness of the thinner part or 20 mm, whichever is less, shall be corrected by welding to acceptable dimensions prior to joining the parts by welding. Root gaps larger than this shall only be corrected by welding to an approved procedure.

4.8.2.3.7 Alignment

Members to be welded shall be brought into correct alignment and held in position by tack welds or other external devices. The use of jigs and fixtures is recommended where practicable. Suitable allowances shall be made for distortion and shrinkage.

4.8.2.3.8 Tack welds

The minimum length of a tack weld shall be four times the thickness of the thickest part being joined together. This length may be reduced to 50 mm provided that there is sufficient heat input[1)] from the tack weld to prevent any cracking.

Multiple-pass tack welds shall have cascaded ends[2)].

In addition, tack welds:

a) shall be subject to the same quality requirements as the weld except as noted in (e);

b) shall be deposited with sufficient heat input/arc-energy to prevent cracking;

c) shall be made with electrodes meeting the requirements of final welds;

d) shall be cleaned thoroughly;

e) which are to be incorporated into the final weld using submerged arc welding need not have discontinuities such as undercut, unfilled craters and porosity removed, provided the quality of the final weld is acceptable;

f) which are not to be incorporated into the final weld shall be removed. For statically loaded structures tack welds need not be removed unless otherwise specified.

4.8.2.3.9 Welds for temporary attachments

Welds for temporary attachments shall be made in accordance with approved welding procedures. When they are removed, the surface shall be made flush with the original surface.

4.8.2.3.10 Continuity of backing

Backing for groove (butt) welds shall be continuous for the full length of the joint. Where steel backing is composed of individual lengths of bars, they shall be carefully aligned and welded into one continuous member using complete joint penetration butt (groove) welds. The joints in the backing bars shall be of the same quality as the main joint.

The separation between surfaces of groove (butt) joints on steel backing shall not exceed 2 mm. The use of steel shims is not permitted unless specifically agreed.

4.8.2.3.11 Sealing welds

When sealing or other non-structural welds are specified, relevant preheat requirements shall apply.

4.8.2.4 Details of welding procedures

4.8.2.4.1 Material for extension bars, run-off plates and backings

Extension bars, run-off plates and backings used for the welding of steels up to and including 480 N/mm^2 minimum specified tensile strength shall be any of the steels meeting the requirements of 6.3 of ISO 10721-1:1997.

Extension bars, run-off plates and backings used for the welding of steels of over 480 N/mm^2 minimum specified tensile strength permitted by 6.3 of ISO 10721-1:1997 shall be of the same material as the base material.

4.8.2.4.2 Termination of groove (butt) welds

Groove (butt) welds shall be terminated at the ends of a joint in a manner that will ensure sound welds and full throat thickness. Where possible, this shall be done by the use of extension bars or run-off plates.

When removal of these plates or bars is required, it shall result in a smooth finish in the weld and the main material.

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1) Heat input equals arc energy times the thermal efficiency for the process concerned.

2) Ends of welds in which each subsequent layer or pass is shorter than the previous one, resulting in gradual stepped-down termination.

4.8.2.4.3 Groove (butt) weld backing

Groove (butt) welds made with the use of steel backing shall have the weld metal fused with the backing. Where specified, the steel backing shall be removed and the joint ground or finished smooth.

4.8.2.4.4 Welding quenched and tempered steels

When determining preheat requirements, consideration shall include the additional heat input produced in simultaneous welding on the two sides of a common member or the use of multiple electrodes.

4.8.2.4.5 Multi-process applications

4.8.2.4.5.1 Combination of welding processes in one system

A combination of welding processes in one system of moving-arcs shall be permitted.

4.8.2.4.5.2 Combination of independent welding processes on one joint

Each process shall be approved separately or in combination with other processes.

4.8.2.4.6 Welding procedure documentation

Written welding procedures shall be provided for all welds, and include the following items as applicable:

a) welding process or processes;

b) parent metal specification, thickness and other relevant dimensions;

c) whether shop or site welding is to be performed;

d) cleaning, degreasing, etc.;

e) classification, type and size of electrodes and other consumables;

f) for manual welding, the size of electrode, welding current and length of run per electrode or fillet weld leg length and number of runs;

g) for semi-automatic, automatic and mechanized welding, the size of electrode, welding current, arc voltage, speed of travel, wire feed speed, electrode extension or fillet weld leg length and number of runs and rate of flow of gas and/or consumption of other process materials as appropriate;

h) when applicable, the temperature and time adopted for drying/baking of welding consumables before use;

i) sketch showing edge preparation, fit-up and approximate number and arrangement of runs in multi-run welds;

j) jigging or tacking, backing, etc.;

k) welding positions;

l) welding sequence;

m) minimum preheating and interpass temperature;

n) maximum interpass temperature;

o) back-gouging;

p) post-weld heat treatment;

q) any other relevant information.

NOTE ISO 9956-2 requires many of these items to be included in the welding procedure specification.

4.8.2.5 Stud welding

Stud shear connectors shall be welded in accordance with the requirements of the appropriate national standards.

The requirements for stud material properties together with the related type and number of tests shall be in accordance with the appropriate national standard.

Welding of studs shall not be undertaken when the surface is wet. The studs and the surface to which they are welded shall meet the requirements of 4.5.2.

The studs shall be tested in accordance with the appropriate national standards.

4.8.2.6 Control of distortion and shrinkage stresses

See annex A for guidance.

4.8.2.7 Repairs

When welds do not meet the quality requirements of the applicable standard, their defective portions shall be removed and the weld repaired and reinspected. (See annex B for guidance.)

Where, however, it can be demonstrated by the use of fracture mechanics or other suitable methods of assessment that the defects will not be injurious to the performance of the structure, such defects need not be repaired or rewelded, provided that for any such defect this alternative is acceptable to both the responsible authority and the fabricator.

NOTE See [10] and [11] of Bibliography.

4.8.2.8 Peening

Peening of welds shall be permitted when specified and the appropriate controls are applied.

4.8.2.9 Stress-relief heat treatment

Stress relief shall be carried out in accordance with the appropriate national standard or, in the absence of such standards, as specified.

4.8.2.10 Cleaning of welds

Welding slag shall be removed from the surface of the weld metal before the deposition of a subsequent run. Slag shall be removed from all finished welds.

4.8.2.11 Arc strikes

Arc strikes outside the area of permanent welds shall be avoided. For structures using quenched and tempered steels or designed for fatigue conditions or low temperature service, the surface of the arc strike shall be lightly ground and checked for freedom from cracking using the magnetic particle or dye penetrant method.

4.8.2.12 Welding of steel castings

Fusion welding of steel castings shall be undertaken in accordance with the requirements of the appropriate national standard or, in the absence of such standard, as otherwise specified.

5 Fabrication tolerances

5.1 General

All structural steel shall be within the tolerances specified in this part of ISO 10721 and shall be such that they permit the safe erection of the structure within the specified erection tolerances (see clause 8).

Additional or different tolerances can be specified where necessitated by the nature of the particular building or structure under consideration. Such tolerances shall be compatible with the design recommendations and product standards.

5.2 Cross-section of rolled sections

The cross-sectional tolerances of rolled members (including those used as components of fabricated members) shall be as specified in ISO 657 or the appropriate national standard.

5.3 Cross-section of members fabricated from plates (or built up from sections)

5.3.1 Flanges

The deviations from the specified dimensions shall not exceed those shown in Figure 2.

5.3.2 Web plates

5.3.2.1 Maximum distortion of web

The maximum distortion Δ of web on a gauge length, in any direction, equal to the depth d_1 of the girder shall not exceed $\frac{d_1}{100}$ or 6 mm, whichever is greater (see Figure 3).

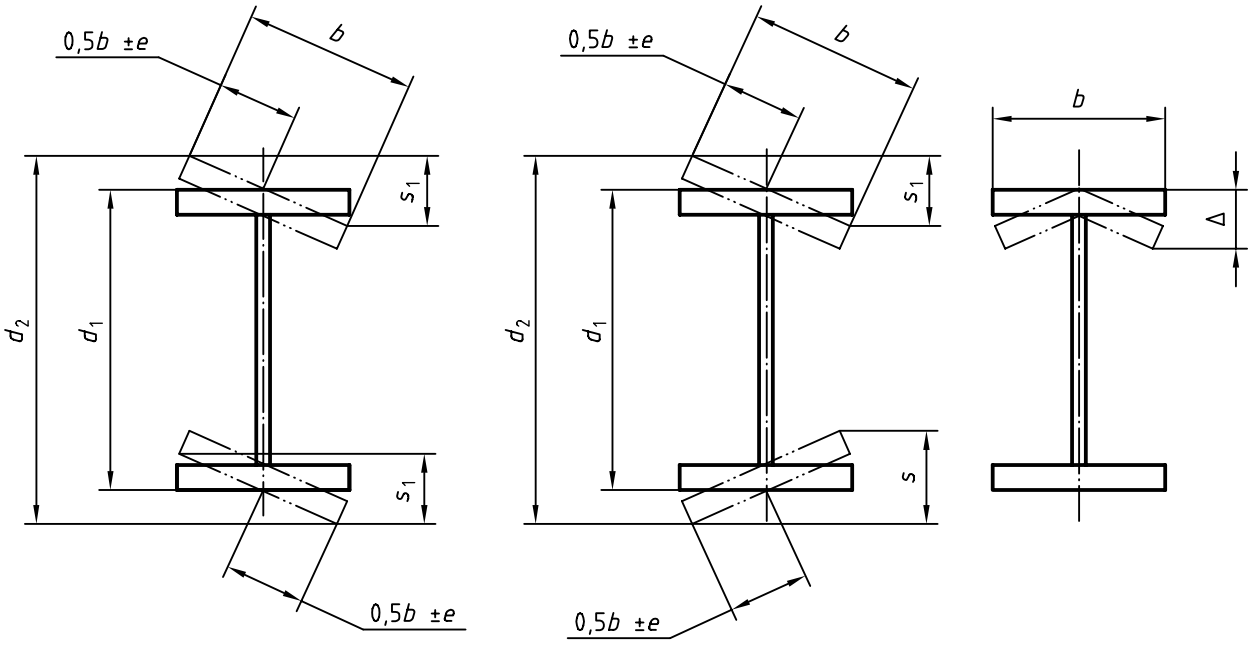
5.3.2.2 Verticality of webs at bearing supports

The deviation from the verticality of the webs at a support, measured by the quantity Δ, shall not exceed $\frac{d_1}{300}$ or 3 mm, whichever is greater (see Figure 4).

5.3.3 Fabricated box section diaphragms

Unless connection requirements necessitate more stringent tolerances, the differences between the diagonal dimensions d_3 and d_4 of box section diaphragms shall not exceed

$\frac{d_3 + d_4}{400}$ or 5 mm, whichever is greater (see Figure 5).



NOTE Where the beams are used as a crane runway, tighter tolerances on the slope of the upper flange and other dimensions may be needed and will be specified by design.

Key

d_1 the average depth measured on the centreline of the web as fabricated; with the following tolerances:

1) ± 3 mm for depths ⩽ 900 mm,
2) ± 5 mm for depths > 900 mm and ⩽ 1 800 mm,
3) ± 8 mm, – 5 mm for depths > 1 800 mm;

b flange width ± 6 mm

e web eccentricity ± 6 mm

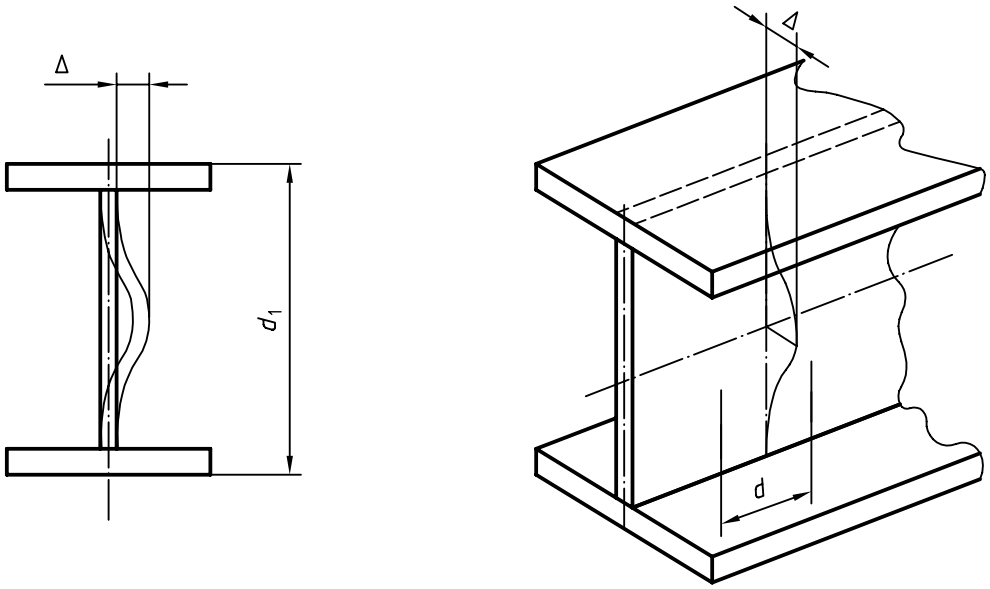
d_2 maximum overall or measured depth, where at any cross-section d_2–d_1 the following tolerances shall apply:

1) + 12 mm for flanges ⩽ 600 mm in width,
2) b/50 for flanges > 600 mm in width

s or s_1 maximum out-of-squareness, 12 mm or b/50, whichever is greater;

Δ maximum out-of-flatness, 6 mm or b/100, whichever is greater.

Figure 2 — Flange out-of-square



d = gauge length

Figure 3 — Flatness of web plates

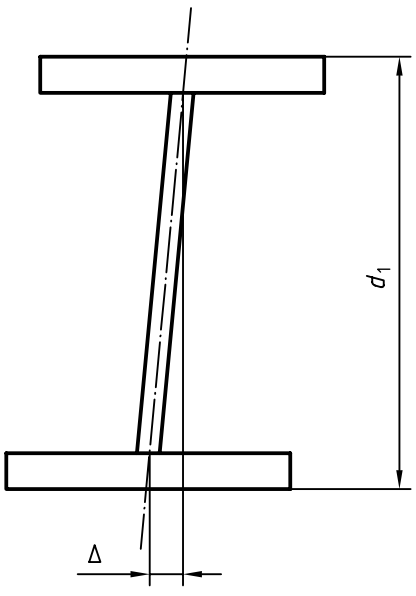


Figure 4 — Deviation from verticality

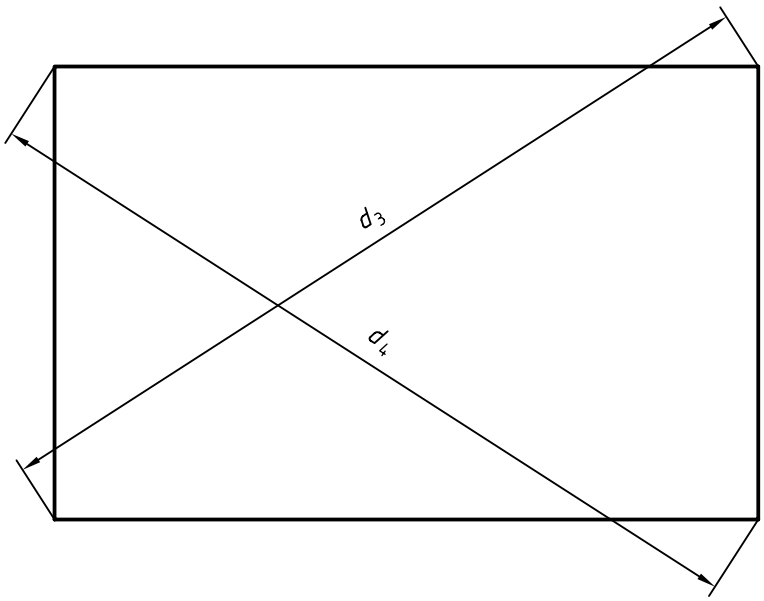


Figure 5 — Prescribed shape of box section diaphragms

5.4 Length

Tolerances on the detailed length of members which are to be framed to other steel parts of the structure shall not be greater than those shown below:

$\leqslant$10 m: $\pm$ 3 mm

$>$ 10 m: $\pm$ 5 mm

For machined finished lengths: $\pm$ 1 mm.

5.5 Straightness in both axes

The maximum deviation of a member from a straight line shall not exceed the following, where l is taken as the distance between the adjacent points of lateral restraint:

a) Compression members: 3 mm or $\frac{l}{1\,000}$, whichever is greater.

b) Beams:

1) Non-hollow sections: 3 mm or $\frac{l}{1\,000}$, whichever is greater.

2) Hollow sections: 3 mm or $\frac{l}{500}$, whichever is greater.

c) All other applications: $\frac{l}{500}$ but not greater than 25 mm.

5.6 Camber

The deviation from specified camber ordinate at the mid-length of the portion to be curved, shall not exceed:

12 mm, or 1 mm per metre length of the curved member, whichever is greater.

6 Erection

6.1 Accuracy of construction

Unless otherwise specified, the accuracy with which the steelwork is fabricated and erected shall be as set out in clause 8 of this part of ISO 10721.

6.2 Marking for erection

Each piece of steelwork shall be suitably marked before delivery in accordance with a marking diagram, and may bear such other marks as will facilitate erection as specified.

6.3 Delivery, storage and handling

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.

All work shall be protected from damage in transit. Particular care shall be taken to stiffen free ends, prevent permanent distortion, and adequately protect all machined surfaces. Materials shall be suitably supported to avoid the possibility of low cycle fatigue. All bolts, nuts, washers, screws, small plates and fittings generally shall be suitably packed and identified.

6.4 Erection of structural steelwork

When erecting the steelwork, the requirements of the appropriate national standard shall be followed in order to ensure safe erection of the structural frame.

Throughout the erection of the structure, the steelwork shall be securely bolted or fastened in order to ensure that it can adequately withstand all loadings liable to be encountered during erection, including, where necessary, those from erection equipment and its operation. Any temporary bracing or temporary restraint shall be left in position until such time as erection is sufficiently advanced to allow its safe removal.

All connections for temporary members provided for erection purposes shall be made in such a manner so as not to weaken the permanent structure or to impair serviceability.

6.5 Alignment

Each part of the structure shall be aligned as soon as practicable after it has been erected. Permanent connections shall not be made between members until a sufficient proportion of the structure has been aligned, levelled, plumbed and temporarily connected to ensure that members will not be displaced during subsequent erection or alignment of the remainder of the structure.

6.6 Protective treatment — Site application

Where a protective treatment is to be carried out or completed on site, the work shall be carried out in accordance with 9.1.

Any damage to the protective treatment which has occurred shall be made good in accordance with 9.3.

7 Supports and foundations

7.1 Foundation anchor bolts

7.1.1 Setting out

Anchor bolts shall be set out within the specified tolerances as given in clause 8.

7.1.2 Positioning in concrete

Anchor bolts shall be adequately restrained during positioning operations. Care shall be taken to ensure that bolts set in sleeves shall be capable of being moved the full extent of the sleeve surrounding them.

7.1.3 Sleeves and pockets

Sleeves and pockets around anchor bolts to provide tolerance for fixing shall be effectively sealed or covered as appropriate to prevent ingress of concrete during placing operations and subsequently kept clean, free from contaminants, debris and liquids until ready for grouting up.

7.1.4 Protection of bolts

Bolt threads and nuts shall be adequately protected against mechanical damage, ingress of cement grout and corrosive elements at all stages of construction.

7.2 Shims

Shims and other supporting devices shall be flat and of adequate strength and rigidity. If shims are to be subsequently grouted, they shall be placed so that the grout totally encloses them.

7.3 Bedding and grouting

7.3.1 Preparation

Except for levelling plates, grouting shall not be carried out until a sufficient portion of the structure (for multi-storey buildings, a sufficient number of bottom lengths of columns) has been aligned, levelled, plumbed and adequately supported by other structural components, which have also been levelled and retained by their permanent connections.

7.3.2 Grouting

7.3.2.1 General

Immediately before grouting, the space under the steel shall be cleared of contaminants and surface water.

7.3.2.2 Pocket bases

Pocket bases containing columns shall be filled with dense concrete having a characteristic cylinder strength at 28 days of not less than that of the surrounding concrete base, with a minimum strength of 20 N/mm^2. At least two-thirds of the embedded length of the column shall be initially surrounded and then remain undisturbed for at least 48 h before removal of any temporary props and wedges.

7.3.3 Encasing of buried steelwork

All buried steelwork in foundations shall be solidly encased in dense concrete having a characteristic cylinder strength of not less than 20 N/mm^2 at 28 days. A minimum cover of 50 mm shall be provided where possible to any steelwork where the surrounding concrete is adjacent to the soil.

8 Erection tolerances

8.1 General

This clause specifies tolerances for building frameworks to ensure structural integrity. For other structures or specific applications, additional tolerances may apply.

Care shall be taken during levelling and aligning the structure to the following tolerances so that no instability occurs.

8.2 Connection to concrete foundations

8.2.1 Position

Anchor bolts shall be set in the concrete in accordance with the erection drawings.

Unless otherwise specified, the position of bolt groups and bolts within groups shall be within the following deviations (see Figures 6 and 8):

a) the established column line (ECL) is the actual field line most representative of the bolt groups set out along that line. The ECL shall be within 5 mm of the specified grid line unless agreed otherwise;

b) when a bolt group is shown as being offset on the construction drawings; its position measured parallel and perpendicular to the nearest established column lines shall be within the dimensions given in items c), d) and e);

c) the centre of any anchor bolt group: 6 mm of the established column line;

d) the centre-to-centre of any adjacent bolt groups: 6 mm;

e) the accumulation along any established column line of bolt groups: 6 mm per 30 m length, up to 25 mm maximum;

f) the centre of any bolt within the group: 3 mm for bolts rigidly cast in, or 6 mm for bolts in sleeves.

8.2.2 Projection

Anchor bolts shall be set perpendicular to the theoretical bearing surface (unless shown otherwise) and the projection of the end of the bolt shall be within 25 mm above or 5 mm below that specified on the drawings [see Figure 6 a)].

8.3 Column bases

8.3.1 Position in plan

The position in plan of a steel column at its base shall be within 10 mm along each of the principal setting-out axes from its established column line.

8.3.2 Level

The established level plane (ELP) is that which is the most representative of the baseplate level along that line. The ELP shall be within 5 mm of the specified level, unless agreed otherwise.

The level of the steel baseplate shall be within 5 mm from its established level plane [see Figure 6 b)].

8.4 Plumbing and alignment of columns

8.4.1 Plumb of an individual column length

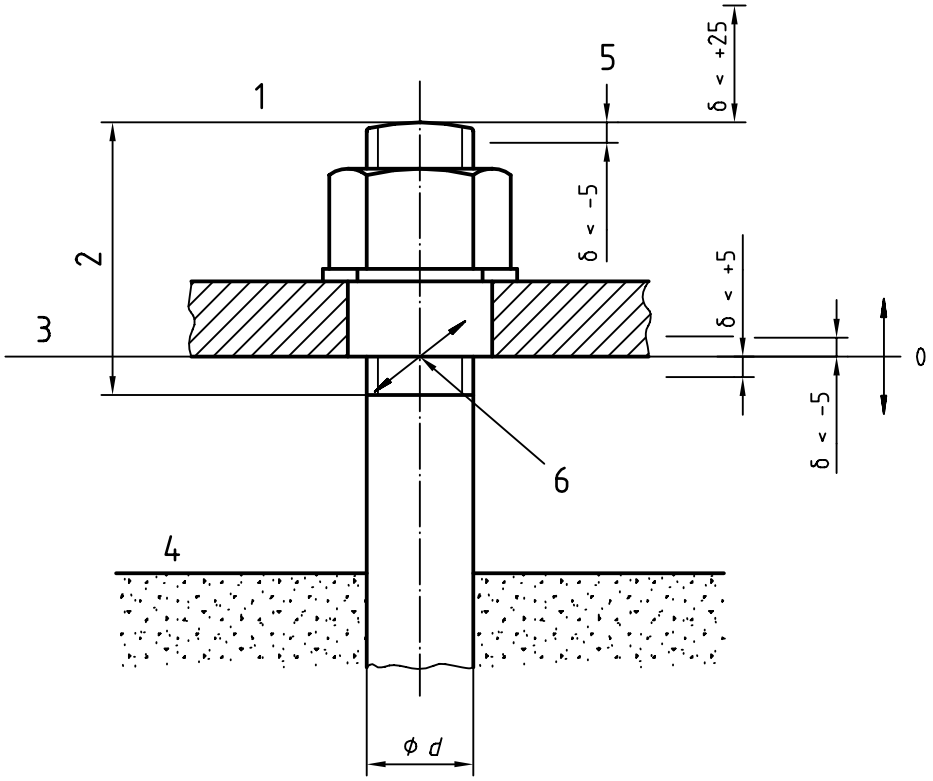
The position of the top of each individual length of column shall be within 1/500 of its height from its actual position at the bottom along each of its principal axes, (see Figure 7) except as follows:

a) portal frame columns measured in the plane of the frame for which no tolerance is given;

b) column adjacent to elevator shafts and to the exterior building line when accuracy shall be within 1/1 000 of its height.

An individual column length is the length between the column's working points, namely the centre of the column cross-section at baseplates, field splices and cap plates.

Dimensions in millimetres



a) Enlarged cross-section through bolt

Key

1 Top of bolts

2 Standard thread length (over 200 mm long) = $2d + 25$

3 Baseplate level

4 Top of concrete foundation

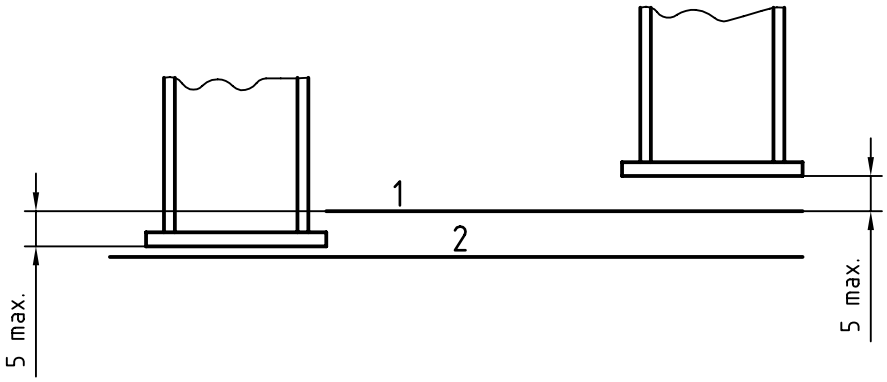
5 Projection of bolt (8.2.2)

6 Position in plan

± 10 mm baseplate (8.3.1)

± 6 mm sleeved bolt (8.2.1f)

± 3 mm cast-in bolt (8.2.1f)



b) Levels of steel baseplates

Key

1 Established level plane (8.3.2)

2 Specified level plane

Figure 6 — Levels of holding-down bolts and baseplates

8.4.2 Plumb over total height of column

8.4.2.1 Interior columns and interior faces of columns

The position of the top-most column length with respect to the actual position at the column base along either of its principal axes shall be within (see Figure 7):

a) 50 mm up to the first 20 storeys;

b) plus a further 2 mm per storey over 20 storeys up to a maximum of 75 mm.

8.4.2.2 Exterior faces of columns and faces of columns adjacent to elevator shafts

As 8.4.1 above but:

a) 25 mm up to the first 20 storeys;

b) 25 mm plus a further 2 mm per storey over 20 storeys up to a maximum or 50 mm (see Figure 7).

8.4.3 Exterior column member working points

At any splice level and at the tops of columns the member working points shall not fall outside a horizontal envelope parallel to the external face of the building, 40 mm wide for buildings up to 90 m long. The width of the envelope may be increased by 12 mm for each additional 30 m, but may not exceed 76 mm (see Figure 9).

8.5 Alignment of beams

8.5.1 Position in plan

The column working line (CWL) is a straight line joining the column working points.

Beams and other steelwork connected to the column at each storey and roof level shall be within 5 mm of the column working line (see Figure 10).

8.5.2 Elevation of members

Elevations of the ends of members shall be within 10 mm of the specified member elevation. Allowances shall be made for initial base elevation, column shortening, differential deflections, temperature effects and other special conditions, but the maximum deviation from the specified slope shall not exceed $L/500$. The difference from the specified elevation between member ends that meet at a joint shall not exceed 5 mm (see Figure 10).

8.6 Fit of compression joints

The individual fabricated pieces forming the compression joint shall be centred with one another. Gaps shall not exceed 6 mm.

Where the gap exceeds 1 mm, but is less than 6 mm, and sufficient contact area does not exist, the gap shall be packed out with steel shims to achieve the necessary contact area.

9 Corrosion protection of steelwork

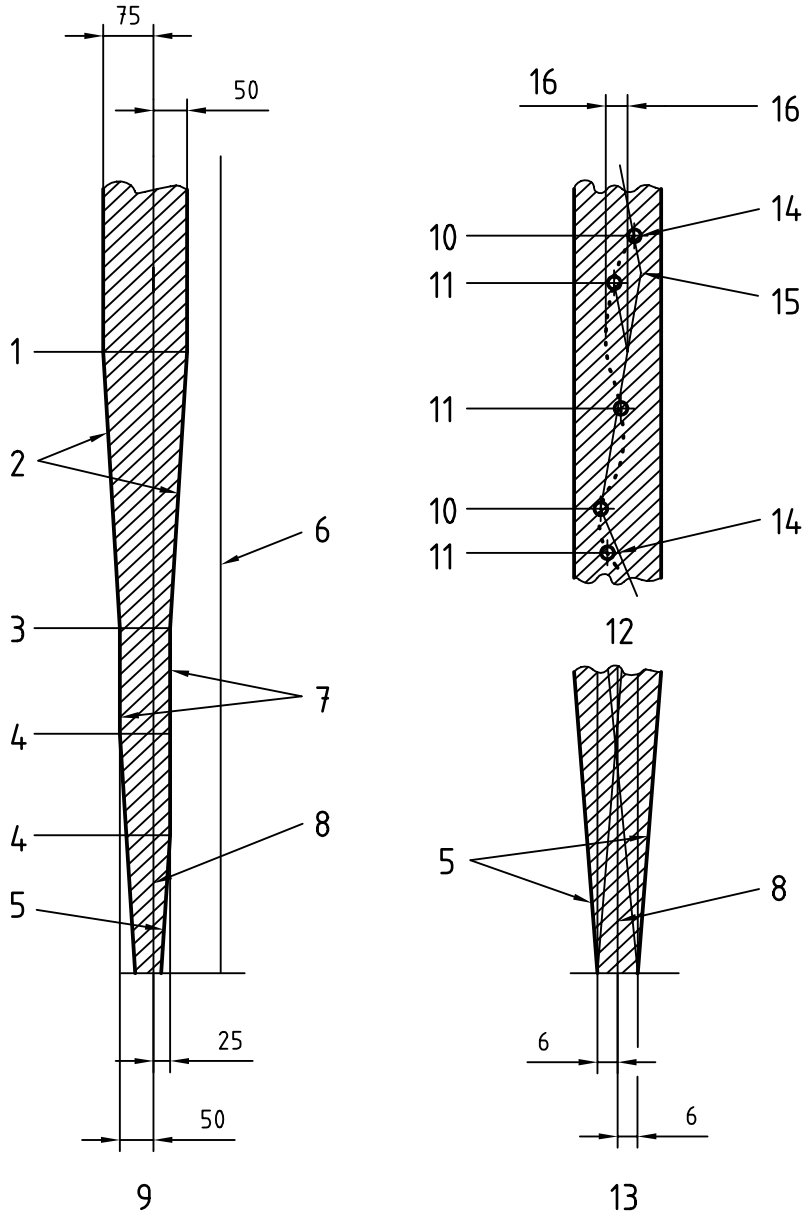
9.1 General

The protective system shall be approved by the designer and shall be carried out in accordance with the instructions in ISO 12944 for paint systems and the guidance in ISO 14713 for metallic coatings.

9.2 Surface preparation

The surface preparation required shall be specified as part of the protective system.

Dimensions in millimetres



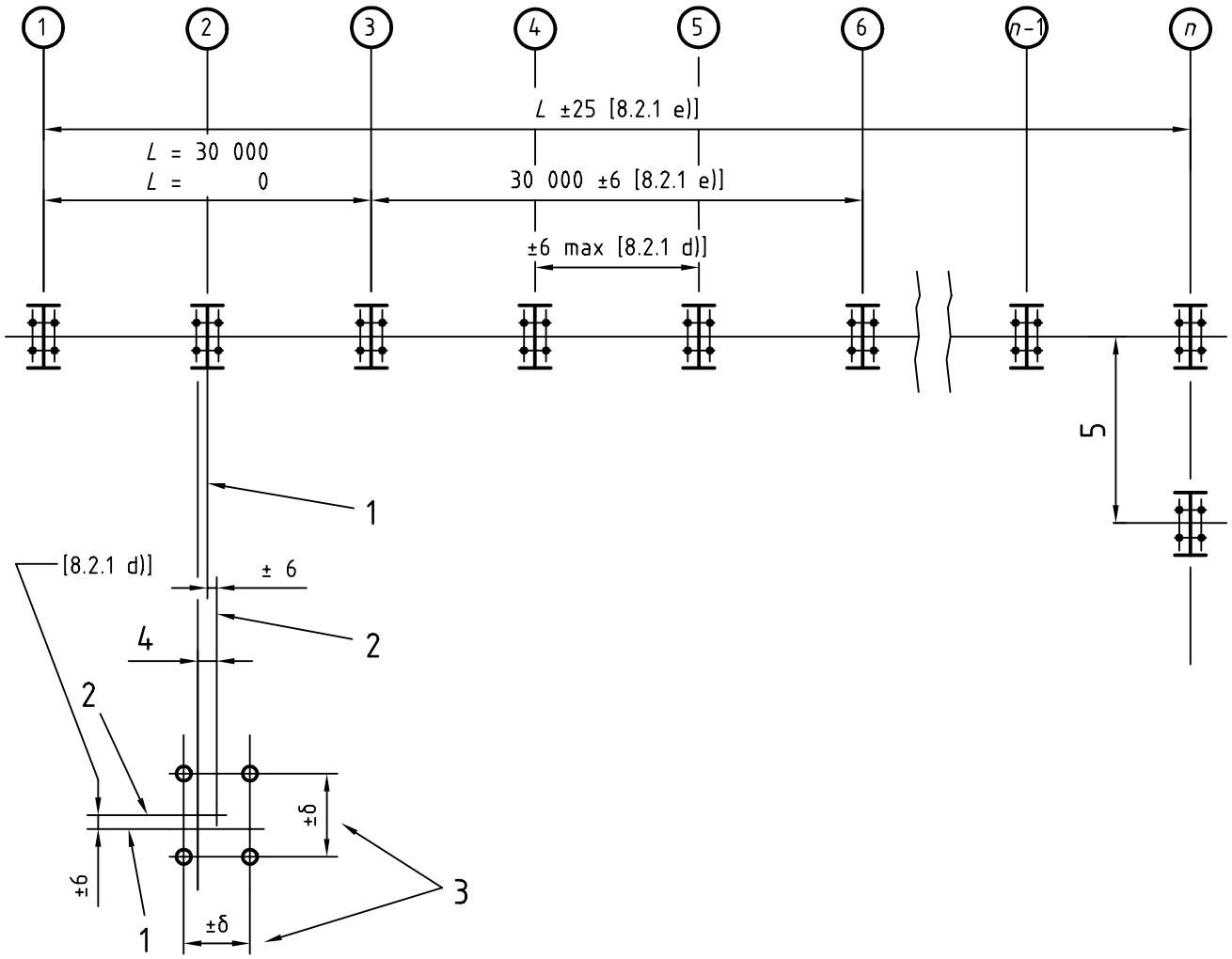
Key

1 36th floor
2 Slope 5 mm per storey
3 20th floor
4 Elev. varies
5 Slope 1/500
6 Building line
7 Plumb
8 Established column line
9 Envelope within which all working points must fall
10 Splice
11 Braced point
12 Individual column sections within envelope defined at left
13 Tolerance on location at working point at base
14 Working point
15 Maximum out-of-plumb of individual shipping piece as defined by straight line between working points $\leqslant$ 1/500
16 Maximum out-of-straightness between braced points L/1000 where L is the distance between braced points

NOTE The plumb line through the base working point for an individual column is not necessarily the precise plan location, because it deals only with plumbness tolerance and does not include inaccuracies in location of established column line, foundations and anchor bolts beyond the erector's control.

Figure 7 — Exterior column tolerances normal to building line

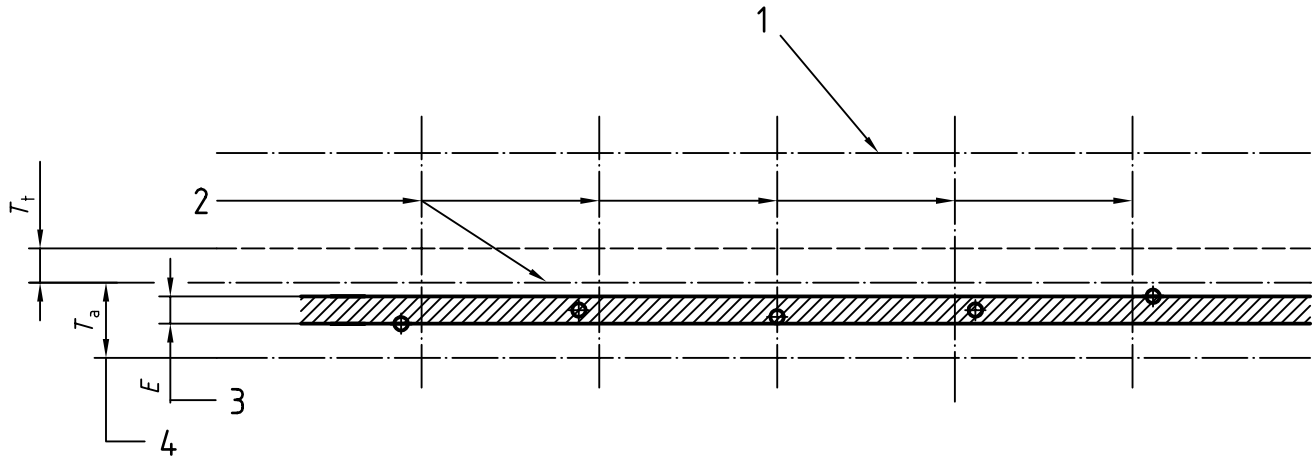
Dimensions in millimetres



Key

1 Grid
2 Anchor bolts
3 $\delta = 3$ mm for bolts rigidly cast in 5 mm for bolts in sleeves [8.2.1 f)]
4 ECL to be within 3 mm of specified grid lines [8.2 b)]
5 ± 6 max. deviation. Also applies if column offset from main column line
n Total number of columns

Figure 8 — Tolerances on anchor bolt placement (see 8.2.1)



Key

1 Building line

2 Established column lines

3 Maximum envelope for working points of all columns at any given elevation: E = 40 mm for up to 90 m of length; over 90 m add 12 mm for each 30 m of length with 75 mm total

4 Column plumbness tolerance — see Figure 8

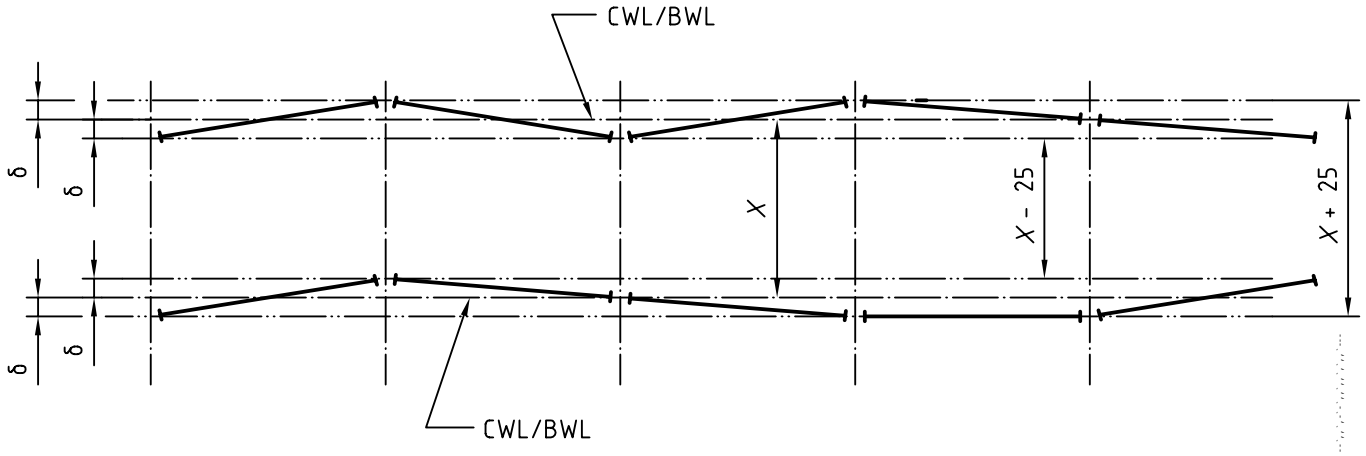
⊕ column working points

NOTE At any splice elevation, envelope ‘E’ is located within the limits T_a and T_t.

At any splice elevation, envelope ‘E’ may be located offset from the corresponding envelope at the adjacent splice elevations, above and below, by an amount not greater than $\frac{1}{500}$ of the column length.

Figure 9 — Tolerances in plan at any splice elevation of exterior columns

Dimensions in millimetres



≤ 5 mm in plan from CWL (8.5.1)

≤ 10 mm in elevation from BWL (8.5.2)

Figure 10 — Alignment of beams

9.3 Protective treatment

The protective treatments shall be carried out in accordance with the specification.

Areas of steel which are not to be treated or coated, or are to be kept clean and free from loose rust, oil, loose scale, etc. shall be specified as such on the drawings.

Surfaces in contact but inaccessible after assembly shall receive their specified treatment before assembly. This condition does not apply to the interior of structurally sealed hollow members.

Hot-dip galvanizing shall be in accordance with ISO 1461 and thermal spraying in accordance with ISO 2063.

Electroplating of bolts shall be in accordance with ISO 2081 and ISO 2082 for zinc and cadmium coatings respectively.

Any damage to the protective treatment which occurs shall be made good. Repairs shall be carried out in accordance with the recommendations of the manufacturer of the treatment system and to the approval of the designer.

Joints to be site-welded and surfaces to which shear connectors are to be welded shall be kept free of primer and any other coating which could be detrimental to achieving a sound weld, except that sheet steel decks may be welded to clean primed steelwork.

Welds and adjacent parent metal shall not be painted prior to their deslagging, inspection and approval.

10 Control in fabrication

10.1 Certification

10.1.1 Availability of certification standards

Where national certification schemes are available for fabrication, these shall be acceptable provided that the following aspects are addressed:

a) engineering and supervisory personnel (see annex C);

b) supply of materials;

c) qualification of operators;

d) qualification of procedures;

e) maintenance of ancilliary equipment.

Factors to be considered when assessing firms using welding as a prime means of fabrication are given in ISO 3834.

10.1.2 Certification scheme having limited coverage

Where national certification schemes cover only some of the aspects of 10.1.1, the ISO 9000 series shall be used to guide the appropriate authority concerning certification standards.

10.1.3 Non-certification

When a facility is not certified, the requirements in 10.1.2 shall be met.

10.2 Control of works

10.2.1 Delivery of materials and components

10.2.1.1 Documentation

All documentation in relation to the delivery of structural steel in sections or plates, structural or general-purpose fasteners, welding consumables, paints and other corrosion-preventative materials shall be checked against the order and items delivered, and any discrepancy noted and remedial measures taken to rectify the discrepancy.

10.2.1.2 Cut edges

Cut edges shall be compatible with any further processes necessary to produce the finished component.

10.2.1.3 Drilling and punching

Holes shall be formed in accordance the provisions of 4.6.

10.2.1.4 Shop assembly of components

Shop assembly of components shall be in accordance with the provisions of 4.5.3, 4.7, 4.8.2.4 together with 8.8.2.3 of ISO 10721-1:1997.

10.2.1.5 Dimensional corrections

All individual components and pre-site assemblies of components shall be checked for dimensional accuracy. Prior to checking, the components shall be supported in such a manner as to cause negligible distortion. The accuracy of measuring instruments and the effect of temperature shall also be in accordance with the requirements of 11.2.

10.2.2 Special processes

10.2.2.1 Surface preparation

The surface preparation shall be checked for compliance with ISO 8501-1 and ISO 8501-2, and ISO 8503-1 and ISO 8503-2 as given in ISO 12944-4.

10.2.2.2 Welding preparation and procedures

The welding preparation and procedures shall be checked for compliance with 4.8.2. When shearing or flame-cutting tests for the base metal and production tests for welded joints are required, they shall be undertaken in accordance with appropriate national standards and shall meet the prescribed acceptance criteria.

10.2.3 Weld examinations

Guidance on testing and inspection of welding is given in annex D.

10.2.4 Final inspection

Prior to despatch from the works, all components shall be checked that they have their appropriate corrosion preventitive coatings, erection markings and have been stacked so as to prevent damage to them (see 6.2, 6.3 and 9.3).

10.2.5 Qualification of personnel

All personnel shall be suitably qualified for the tasks for which they are appointed, in accordance with annex C.

11 Control and inspection during erection

11.1 General

The extent of inspections shall be determined according to the importance of a connection in the structure. If considerable damage can be expected in the event of failure, detailed quality controls shall be specified. If special loading is envisaged or the structure is of special nature, detailed control shall also be specified in the contract documents.

When specified in the contract, the structural steelwork shall be trial-assembled at the fabricator's works.

It is important that a plan be established coordinating all matters affecting erection which takes into account all limitations relating to access, storage, the size and mass of components, together with the amount of pre-assembly at ground level and the planned sequence of erection.

11.2 Inspection

All operations which have been carried out on site shall be checked so as to ensure that they comply with the appropriate procedure specified in the contract documents.

The erection tolerances specified in clause 8 shall take into account the following conditions:

a) **Measuring instruments**

1) Inherent tolerances exist in optical and electronic equipment.

2) Steel tapes are subject to inaccuracies due to sag, tension, slope and temperature variations.

b) **Construction**

1) Where buildings in the construction phase are subject to increasing loads which may cause movement, it will be necessary to set a construction datum against which erection tolerances shall be checked.

2) Temperature effects shall be considered, and it may be necessary to specify a temperature at which erection tolerances shall be checked.

3) Axial shrinkage of columns will occur due to dead loads and construction loads, and shall be considered when comparing floor levels with external benchmark levels.

4) Rolling and fabrication tolerances of the steel column profile and straightness shall be considered as to their effect on erection tolerances.

11.3 Temporary works and supports

The requirements for preserving stability at all stages of erection shall be understood by those responsible for the erection work and procedures shall be strictly followed. Specified temporary supports shall be of adequate design and construction and shall be used in the way intended. Improvised supports shall only be employed after approval by the engineer.

The setting out and alignment of all temporary works shall be carried out to the same standard as for permanent works.

Annex A
(informative)

Guidance for control of distortion and shrinkage

A.1 Before the start of welding on a member or structure in which distortion is likely to affect the adequacy of the structure, a programme of welding sequence for control of distortion should be developed.

A.2 Welds should be deposited in a sequence that will balance the applied heat of welding while the welding progresses.

A.3 The weld procedure and sequence used in fabrication should be such as to minimize distortion and shrinkage.

A.4 The direction of the general progression in welding on a member should be from points where the parts are relatively fixed in position with respect to each other toward points where they have a greater relative freedom of movement.

A.5 Joints expected to result in significant shrinkage should be welded first while conditions of minimum restraint prevail.

A.6 All shop splices in component parts should be completed before assembly of the fabricated member.

A.7 In making welds under conditions of severe restraint, the welding should be carried out continuously to completion or to a point that will ensure freedom from cracking before the joint is allowed to cool below the minimum specified preheat and interpass temperature.

Annex B
(informative)

Guidance for repair of welds

B.1 Welds should be repaired in accordance with the requirements for testing and inspection of the original weld.

B.2 The removal of the weld metal or portions of base metal should be carried out by any appropriate method such that the surfaces of remaining weld or base metals are smooth. Oxygen gouging should not be used on quenched and tempered steels. Defective portions of the weld should be removed without substantial removal of the base metal.

B.3 Where work performed subsequent to the making of a deficient weld has rendered the weld inaccessible or has caused new conditions that would make the correction of the deficiency dangerous or ineffectual, the original conditions should be restored by removing welds or members or both, before making the corrections, or else the deficiency should be compensated by additional work done according to an approved revised design and procedures.

B.4 Improperly fitted parts may be cut apart and rewelded subject to clause B.3. Members distorted by welding shall be straightened by mechanical means, by carefully supervised application of a limited amount of localized heat, or by a combination of both methods. The temperature of heated areas as measured by approved methods should not exceed 590 °C or 20 °C below the tempering temperatures of the steel, whichever is lower, for quenched and tempered steels nor 650 °C for other steels. Account should be taken of existing stress.

Annex C
(informative)

Guidance for the qualification of personnel

C.1 Competence

Care should be taken to ensure that all persons engaged in the work are only called upon to carry out tasks which should be reasonably expected from their level of competence.

C.2 Qualification of welders

Welders should be qualified in accordance with the requirements of ISO 9606-1 or the appropriate national standards.

C.3 Qualification of non-destructive testing (NDT) inspection personnel

The successful application of testing depends on the knowledge and experience of the personnel responsible for producing the test procedures and the technical competence and ability of the practitioner to carry out the procedural requirements and to interpret results.

C.4 Qualification of steel erection personnel

All steel erection personnel should be qualified in accordance with the requirements of the national agreements.

Unless otherwise agreed between the contracting parties, the appropriate level and category of certification of personnel should be in accordance with the terms of those obtained from an agreed nationally accredited certification scheme.

Annex D
(informative)

Testing and inspection of welds

D.1 Inspection stages

The procedures for testing and inspection of welded structures depend on many factors which are related to fitness for purpose, and depend on such variables as the importance of the structure or member, service temperature, material quality, strain rate, type of detail and workmanship. Where any of the requirements listed below are not addressed in the relevant national standards, the requirements given in this annex should apply. The main stages for testing and inspection to control weld quality are as follows:

a) procedure trials (see D.2);

b) welder trials (see D.3);

c) production control (see D.4);

d) final acceptance (see D.5).

D.2 Procedure trials

D.2.1 Destructive testing

Prior to production, destructive testing should be carried out in accordance with ISO 4136, ISO 5173, ISO 5177 as appropriate, or the appropriate national standards,to demonstrate that the mechanical properties of the weld metal and heat affected zone do not undermatch the minimum properties specified for the parent metal. Additionally, hardness tests should be carried out on weld metal, heat-affected zone and parent material of a macrosection from a weld procedure test sample, and the results recorded and submitted for approval.

D.2.2 Special testing for dynamically loaded structures

For groove welds and heat-affected zones of groove joints in bridges or other specialized structures, destructive testing should include the tests specified in D.2.3 or as required by appropriate national standards.

D.2.3 Weld metal and heat-affected zone (HAZ) Charpy V-notch impact test requirements for tension areas

D.2.3.1 Groove welds in butt joints including corner and tee joints

The following requirements for weld metal notch toughness should be the minimum requirements for the thinner parent plate or part of the rolled section at the joint.

a) For regions with a design tensile stress above 75 N/mm^2, the weld metal notch ductility requirements can be reduced to $\frac{\sigma_y}{355} \times \frac{t}{2}$ J or 18 J average energy absorption, whichever is the greater, at the minimum design temperature as specified for material section

   where

   σ_y is the specified minimum yield strength, in newtons per square millimetre (N/mm^2);

   t is the relevant thickness, in millimetres.

b) Where the design tensile stress is $\leqslant$ 75 N/mm^2, the weld metal notch ductility requirements can be reduced to $\frac{\sigma_y}{355} \times \frac{t}{4}$ J, or 18 J average energy absorption, whichever is the greater, at the minimum design temperature as specified for material selection.

c) For groove (butt) welds, including corner and T-butt welds, transverse to carrying the main tension stress, for which the procedure test tensile and macrosection hardness test show the weld metal to overmatch the strength of the parent plate, the minimum requirements for the weld metal, calculated in accordance with a) and b), may be reduced to 27 J at – 20 °C.

D.2.3.2 Heat-affected zone (HAZ)

The fusion boundary region of the HAZ of groove (butt) welds, including corner or T-groove (butt) welds, which are transverse to and carry the main tension stress should have the notch ductility requirements given in Table D.1.

Table D.1 — Heat-affected zone test requirement for notch ductility in transverse groove (butt) welds

Heat welding input	Specified minimum yield strength of parent plate	
	$\leqslant$ 355 N/mm^2	$>$ 355 N/mm^2
$\leqslant$ 5 kJ/mm	No test requirement	As given in D.2.3.1 a) when specified
$>$ 5 kJ/mm	As given in D.2.3.1 a) when specified	As given in D.2.3.1 a)

D.2.3.3 Location and orientation of specimens for Charpy V-notch impacts tests

For Charpy tests on the weld metal, the length of specimen should 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 centreline of the weld joint. For symmetrical and asymmetrical double-V, double-J and double-bevel joint preparations, the specimen should 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 should be taken from the side with the smaller preparation. For single-V, single-J and single-bevel joint preparations, the specimen should be cut so that one face is essentially 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 should 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 midthickness of the specimen should lie on the fusion boundary of the HAZ of the weld under test. The specimens should be cut so that one face is essentially parallel to, and within 3 mm of, the original plate surface.

Inspection procedures for non-destructive testing examination, together with acceptance criteria, should be in accordance with the appropriate national standards. The extent of such inspection should be in accordance with the relevant contract documents.

D.2.3.4 Number of specimens

Initially, three specimens for each weld or HAZ under consideration should be taken and, depending on the test results for these specimens (see D.2.3.5 below), a further three specimens can be taken from the same joint.

D.2.3.5 Testing and acceptance criteria

The initial three specimens should 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 should be tested and the results added to those previously obtained and a new average value calculated.

The new average value should not be less than the specified minimum average value. Not more than three of the total of six results should 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 should be less than 50 % of the specified minimum average value. If the results fail to comply with the above requirements, the procedure concerned should be rejected. The cause of failure should be established and, depending on the cause, either the procedure test should be repeated or a new procedure test shall be established and approved.

D.2.4 Inspection of welds

Non-destructive testing and/or sectioning of the test welds should be carried out in accordance with the appropriate national standards to demonstrate that any weld discontinuities present do not exceed the limits specified.

In the absence of appropriate national standards, acceptance levels for procedure trial weld quality should be selected such that they are generally higher than those required for final acceptance of the production welds (see D.5).

D.3 Welder trials

Following procedure approval, welder trials in accordance with ISO 9606-1 or the appropriate national standard on each relevant joint type should be carried out by all welding personnel before being engaged on production.

In the absence of appropriate national standards the acceptance levels for weld quality in welder trials should be selected such that they are similar to those for the procedure trials (see D.2.4).

D.4 Production control

D.4.1 General

Assessment of weld quality during production by periodic non-destructive examination is recommended. ISO 5817 gives a range of quality levels from which, for the purpose of general quality control, a selection may be made. Appropriate measures should be employed such that corrective actions can be implemented before any lapses in quality are such that the welds would fail to conform with the final acceptance standards (see D.5).

D.4.2 Special structures

In the absence of appropriate national standards for bridges and other specialized structures, the mechanical properties of transverse groove (butt) welds should be verified by destructive testing run-off plates in accordance with D.4.3.

D.4.3 Testing of run-off plates

D.4.3.1 Test plates

When required in national standards, approximately one in five pairs of "run-off" plates for transverse groove (butt) welds in tension flanges and 1 in 10 pairs for other groove (butt) welds should be production test plates. The combined size of each pair of production test plates should be adequate for the number and size of specimens to be tested. The material quality of the "run-off" plates should be the same as that of the plates to be welded. On completion of the welds, the "run-off" production test plates should not be removed until they have been marked in a manner to identify them with the joints to which they are attached.

D.4.3.2 Testing

The following tests complying with the requirements should 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 should be made; the tensile strength should not be less than the corresponding specified minimum value for the parent metal. Testing shall be in accordance with ISO 4136.

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

b) Bend test

For materials less than 10 mm in thickness, one transverse root bend test and one transverse face bend test should be made. For material 10 mm in thickness and over, one side bend test comprising sufficient specimens to cover the full plate thickness should be made. The diameter of the former and the angle of the bend used in the test should comply with the requirements of ISO 5173 and ISO 5177. On completion of bending any defects in the tension surface of the test specimen should be investigated and their cause established, before the specimen is either accepted or rejected. Slight tearing at the edges of the test specimen should not be a cause for rejection.

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

c) Charpy V-notch impact test

Charpy V-notch impact tests should be made on weld metal in butt welds transverse to the carrying and main tension stresses.

Additionally, where specified, Charpy V-notch impact tests should be made on the fusion boundary region of the HAZ and should comply with the requirements of D.2.3.

D.4.3.3 Re-welding and re-testing

In the event of failure to meet the test requirements of D.4.3.1 and D.4.3.2, the results should be submitted to the designer 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 should be cut, re-welded and the tests repeated.

D.5 Final acceptance

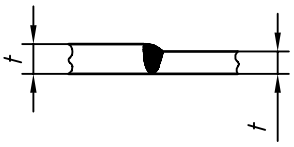
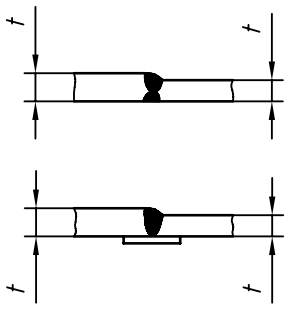
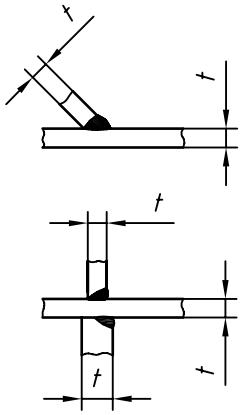
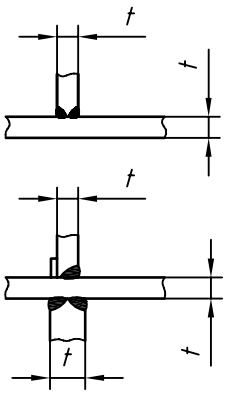
D.5.1 General

Unless otherwise specified in the appropriate national standards, all welds should be visually inspected. Where in addition non-destructive testing should be applied in accordance with Table D.2, quality should conform with the requirements of Table D.3, provided that the toughness values of parent and weld metal and heat-affected zone by specification are not less than specified for weld metal in D.2.3.1.

Normal quality should be assumed for statically loaded building structures.

For bridges and other dynamically loaded structures, other qualities may apply to specific joints as indicated on the drawings (see D.5.2 below).

Table D.2 — Scope of inspection

Part A: Type of joints and thicknesses requiring non-destructive testing					
		Thickness when non-destructive testing becomes mandatory — Normal and fatigue quality level [a, b]			
Weld type		**Butts full and partial penetration (including butts with reinforcing fillets)**			
Joint type		**In-line butt**		**Tee and cruciform**	
Procedures		**S/S**	**D/S and S/S + B**	**S/S**	**D/S and S/S + B**
Examples **Key** t_1 = greatest t at a joint z_1 = greatest z at a joint S/S = single-sided D/S = double-sided B = backing NM = not mandatory					
NDT Method	**Quality level**	t_1 mm	t_1 mm	t_1 mm	t_1 mm
Magnetic particle inspection	Normal FAT 71 to 140	< 10[c] All	< 12[c] All	⩾ 20 All	⩾ 20 All
Ultrasonic testing	Normal FAT 71 to 140	⩾ 10[d] ⩾ 8	⩾ 12[d] ⩾ 8	⩾ 12 ⩾ 12	⩾ 20 ⩾ 12
Radio-graphic testing	Normal FAT 71 FAT 90 to 140	NMF < 8 All	NMF < 8 All	NM NM NM	NM NM NM

a There is no mandatory requirement for NDT of minimum quality welds.

b The requirements of this table shall not preclude the use of non-destructive testing outside the limits shown should the results of visual inspection or NDT indicate that a lapse in quality may have occurred in specific joints.

c Radiographic testing may be used instead of MPI for detection. MPI may be needed to assist evaluation (see Table D.3).

d Radiographic testing may be used instead of ultrasonic inspection for detection if t_1 > 20 mm. Ultrasonic testing may be needed to assist evaluation (see Table D.3).

Table D.2 *(continued)* **— Scope of inspection**

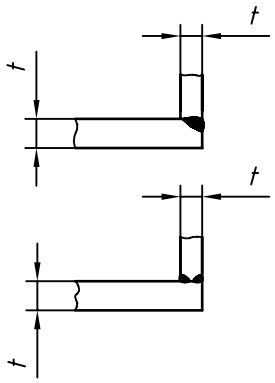
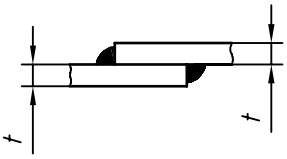
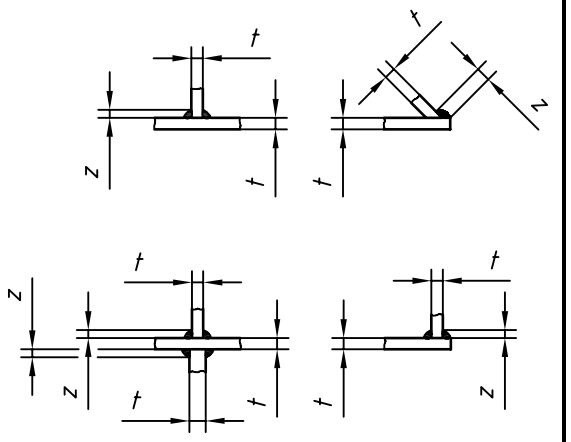
Part A: Type of joints and thicknesses requiring non-destructive testing			
Thickness when non-destructive testing becomes mandatory — Normal and fatigue quality level[a, b]			
Butts full and partial penetration (including butts with reinforcing fillets)	**Fillet**		
Corner	**Lap**	**Tee, cruciform and corner**	
All	**All**	**All**	
			
t_1 mm	t_1 mm	t_1 mm	z_1 mm
⩾ 20 All	⩾ 20 All	⩾ 20 All	NM All
⩾ 30 ⩾ 12	NM NM	NM NM	⩾ 20 ⩾ 20
NM NM NM	NM NM NM	NM NM NM	NM NM NM

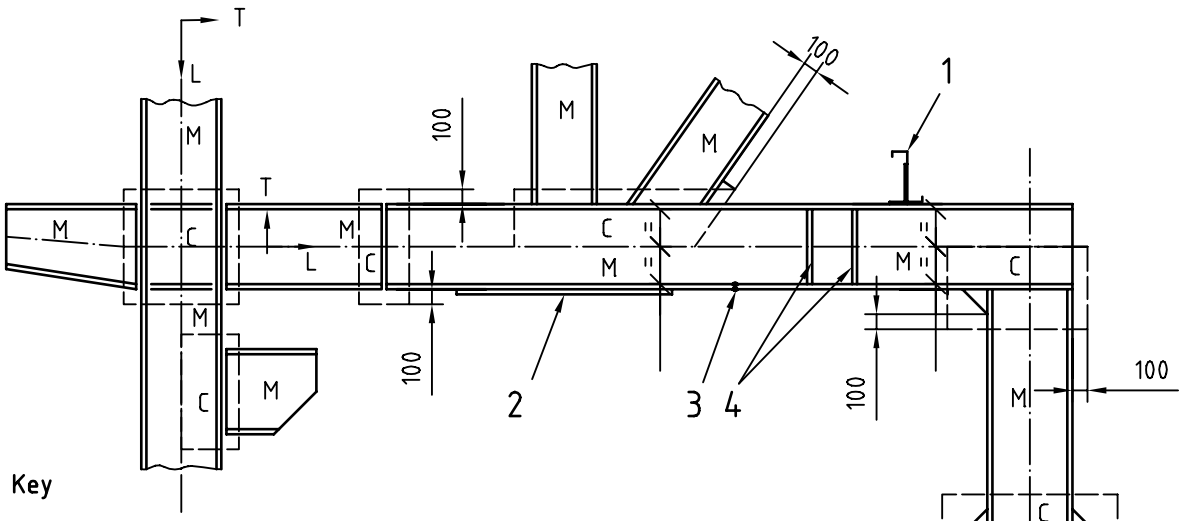
Table D.2 *(end)* **— Scope of inspection**

Part B: Frequency of testing of joints identified in Part A as requiring NDT							
Categories of joint types according to location and orientation in structure (see figure below)			**Frequency of testing according to required quality level** [a]				
			Normal	**FAT 71**	**FAT 90**	**FAT 112**	**FAT 140**
Connection zones	Shop welds		First 10 identified joints of each type having same basic dimensions material grades and weld geometry and welded to same procedures. Thereafter 1 in 4 joints of each type (if first 10 have complied with Table D.3)	All identified joints			—
	Site welds		All identified joints				—
Member zones	Built-up members	Transverse butts in web and flange plates before assembly Transverse fillet welds at ends of lap joints	As for connection zone shop welds	All identified joints			—
		Longitudinal welds	0,5 m in each 10 m, or part thereof, of all identified joints including:				All identified joints
			1 in 4 weld ends	All weld ends		All stop/starts	
	Secondary attachment welds	e.g. for fixing purlins, side rails, buckling stiffeners, etc.	1 in 20 attachments	1 in 4 attach-ments	All attach-ments	—	—

[a] Where only partial inspection is required, the joints for testing shall be selected on a random basis, but ensuring that sampling covers the following variables as widely as possible: joint type, material grade and welding equipment.

Part C: Definition of zones and weld orientations

Dimensions in millimetres



Key

C	Connection zones
M	Member zones
—·——·—	Member axis
– – – – –	Boundary of connection and member zones
T	Transverse to member axis (any direction)
L	Longitudinal (parallel to member axis)
1	Purlin, side rail attachment or similar
2	Cover plate
3	Flange butt
4	Buckling stiffeners

All welds in connection zones shall be treated as transverse.

Table D.3 — Acceptance requirements for production welds in steel structures

Feature	Parameter	Weld type	Particular conditions (Note 1)	Figure D.1 ref.	Dimensions	Acceptance criteria according to required class (Notes 2, 3 and 6)						Remedial actions
						Minimum	Normal	FAT 71	FAT 90	FAT 112	FAT 140	
Overall weld geometry	Location (Note 5)	All				$D \pm 20$	$D \pm 10$	$D \pm 5$	$D \pm 5$	$D \pm 5$	$D \pm 5$	E
	Weld type	All				D	D	D	D	D	D	E
	Extent (length)	All				$D + 20 - 5$	$D + 10 - 0$	$D + 10 - 0$	$D + 10$	$D + 10 - 0$	$D + 10 - 0$	E
Profile disconti-nuities	Actual throat thickness	All		a), b), c)	a,s ≮ a,s ≯	$D - 1$ (50) $D + 10$	D (50) $D + 5$	D $D + 4$	D $D + 4$	D $D + 3$	D $D + 3$	R DS
	Leg length	Fillet		a)	z ≮	$D - 1$	D (50)	D (50)	D (50)	D	D	E
	Toe angle (interface and interrun)	All	Trans Longl	a), b) a), b)	θ ≮ θ ≮	70° 70°	90° 90°	120° 90°	150° 90°	165° 90°	175° 90°	DS/R DS/R
	Excess weld metal	Butt	Trans Longl	b) b)	h ≯ h ≯	8 8	6 6	5 6	4 5	2 4	0,5 3	DS DS
	Incomplete groove or concave root	Butt	Trans Longl	b) b)	h ≯ h ≯	1 1	0 (50) $0{,}1t$	NP $0{,}1t$	NP $0{,}1t$	NP $0{,}1t$	NP $0{,}05t$	R E
	Linear misalignment	Butt All All	Trans butt Trans cruci Longl	d) e) d), e)	h ≯ h ≯ h ≯	$D + 0{,}4t$ $D + 0{,}7t$ $D + 0{,}7t$	$D + 0{,}2t$ $D + 0{,}4t$ $D + 0{,}4t$	$D + 0{,}1t$ $D + 0{,}2t$ $D + 0{,}4t$	$D + 0{,}05t$ — $D + 0{,}4t$	$D + 0{,}05t$ — $D + 0{,}4t$	$D + 0{,}05t$ — $D + 0{,}4t$	E E E
Surface-breaking disconti-nuities	Undercut (Note 4)	All Fillet All	Trans (not lap joint) Trans (lap joint) Longl	d), e), g) e), g) d), e)	$h_1 + h_2$ ≯ l ≯ $h_1 + h_2$ ≯ l ≯ $h_1 + h_2$ ≯	$0{,}1t$ NL $0{,}1t$ NL $0{,}2t$	$0{,}05t$ NL $0{,}03t$ 10 $0{,}1t$	$0{,}05t$ 25 — — $0{,}1t$	$0{,}03t$ 10 — — $0{,}1t$	NP — — — $0{,}1t$	NP — — — $0{,}05t$	R R R R R
	Lack of root penetration	S/S Butt	Trans Longl	c) c)	h ≯ h ≯	$D + 0{,}1t$ $D + 0{,}2t$	$D + 0{,}05t$(50) $D + 0{,}1t$(50)	— $D + 0{,}1t$	— $D + 0{,}1t$	— $D + 0{,}05t$	— $D + 0{,}05t$	R R
	Porosity	All	Trans Longl	f) f)	d ≯ Σd ≯ d ≯ Σd ≯	3 15 [100] 3 30 [100]	2 10 [100] 2 20 [100]	1 5 [100] 2 10 [100]	1 5 [100] 1 5 [100]	NP NP 1 5 [100]	NP NP NP NP	R R R R
	Lack of fusion	All		g)	l ≯	10	NP	NP	NP	NP	NP	R
	Cracks	All	At crater Not at crater	g)	l ≯	5 NP	NP NP	NP NP	NP NP	NP NP	NP NP	R R

Table D.3 *(end)*

Feature	Parameter	Weld type	Particular conditions (Note 1)		Figure D.1 ref.	Dimensions	Acceptance criteria according to required class (Notes 2, 3 and 6)						Remedial actions
							Minimum	Normal	FAT 71	FAT 90	FAT 112	FAT 140	
Subsurface disconti-nuities	Lack of fusion/root penetration, slag lines	Butt	All		g)	h ≯		3	3	3	3	3	R
			Trans	full depth	g)	Σl ≯		1,5t [100]	1,5t [100]	NP	NP	NP	R
				h' < 6	g)	l ≯		10	5	NP	NP	NP	R
						l' ≮		10	10	NP	NP	NP	R
				h' > 6	g)	l ≯		NL	10	5	NP	NP	R
						l' ≮		NL	10	10	NP	NP	R
			Longl	full depth	g)	Σl ≯		3t [100]	1,5t [100]	1,5t [100]	1,5t [100]	1,5t [100]	R
				h' < 6	g)	l ≯		NL	NL	10	5	NP	R
						l' ≮		NL	NL	NL	NL	NP	R
				h' > 6	g)	l ≯		NL	NL	NL	10	5	R
						l' ≮		NL	NL	NL	NL	NL	R
	Root gap	Fillet/P/P butt			a), e)	h ≯		2 (100), 3	2	2	2	2	R
	Porosity	All			f)	d ≯				2	1	1	R
						A ≯				3 %	2 %	1 %	
	Cracks	All						NP	NP	NP	NP	NP	R
	Lamellar tears	All	Trans					NP	NP	NP	NP	NP	E
			Longl					Note 9	Note 9	Note 9	NP	NP	

Abbreviated terms

- D As specified on drawings
- DS Dress smoothly
- E Refer to engineer
- NL No limit
- NP Not permitted (applies to discontinuities which are detectable by NDT methods in Table D.2)
- P/P Partial penetration
- R Repair by welding to approved procedure
- S/S Single-sided (including butt welds in hollow sections)
- ≮ Not less than
- ≯ Not greater than
- Σ Sum of
- ( ) Length of weld over which measurement may be averaged (mm)
- [ ] Length of weld over which summation is made [mm]
- — Not applicable

Shaded area — not normally applicable (see Table D.2)

- A Percentage area (of porosity) as seen on radiograph in any 100 mm of weld length
- l length parallel to weld axis

NOTE 1 For definition of orientation see the figure in Table D.2.

NOTE 2 All dimensions are in millimetres unless otherwise noted.

NOTE 3 Thickness applies to minimum member thickness at weld in question. For thicknesses greater than 20 mm, t, shall be taken as 20 mm. Where the permitted size h of a discontinuity is related to t, the maximum permitted value shall not be less than 0,3 mm in any case.

NOTE 4 "lap" shall apply to any fillet-welded attachment whose length in the longitudinal direction exceeds 50 mm.

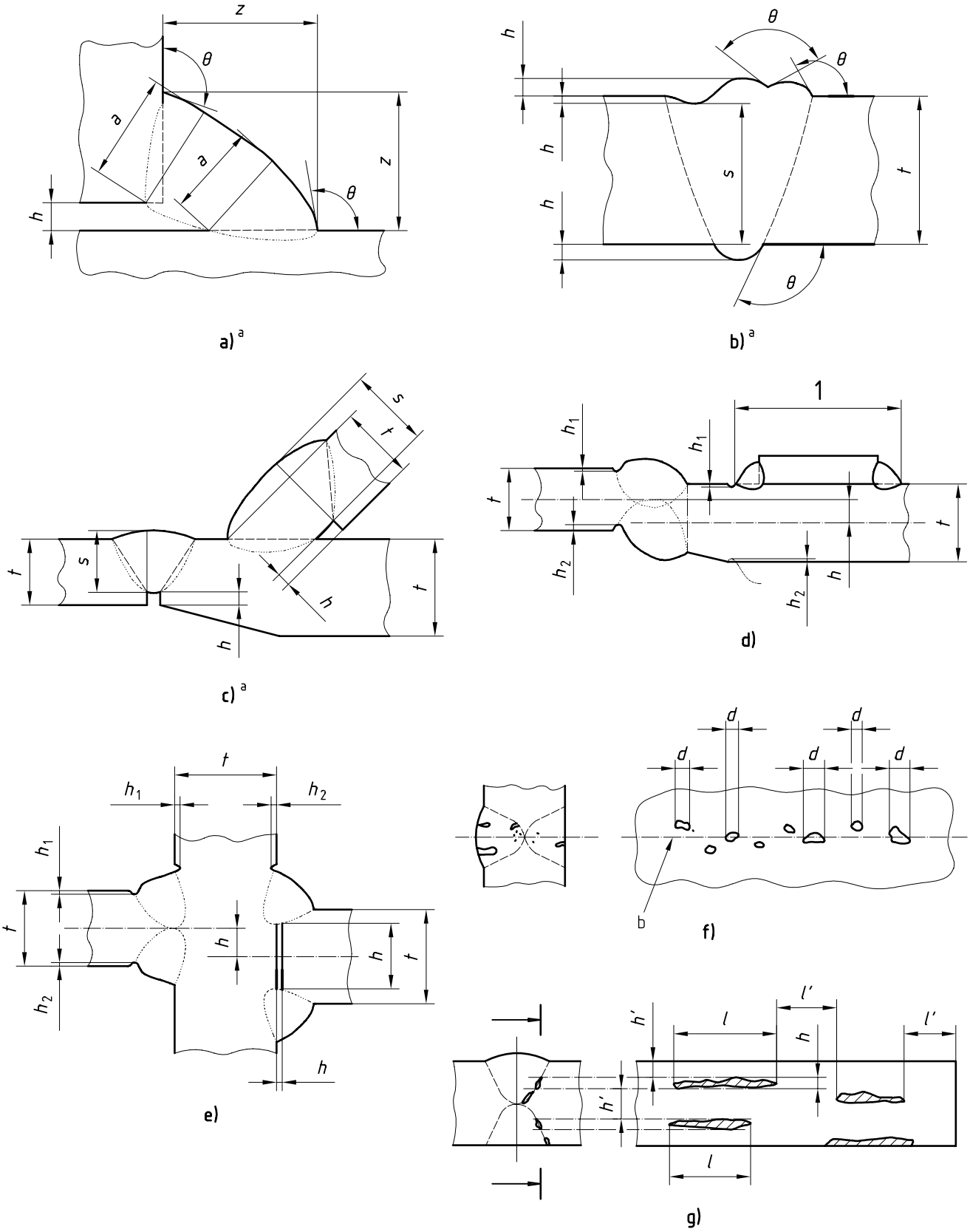
NOTE 5 Subject to any other locational requirements.

NOTE 6 Where more than one requirement is given, both shall apply.

NOTE 7 See Note 3 in Table D.2.

NOTE 8 Any straight line parallel to the weld axis.

NOTE 9 Lamellar tears may only be accepted in longitudinal welds if extent does not exceed limits for lack of fusion in transverse welds.



Key

1 Attachment length

a *a* and *s* are minimum distances

b See note 8 in Table D.3

Figure D.1 — Acceptance requirements for production welds in steel structures

D.5.2 Specification of weld quality levels

Quality levels should be selected for each weld according to the required structural performance of the joints as follows.

i) **Normal quality:** For general structural applications where the fatigue strength requirement does not exceed 56 N/mm^2 at an endurance of 2×10^6 cycles, normal quality will be adequate. Unless another quality is specified in the documentation, it should be assumed that normal quality applies to all welds.

ii) **Fatigue quality:** Where the fatigue strength requirement for a particular joint is in excess of 56 N/mm^2 at an endurance of 2×10^6 cycles, one of the four fatigue qualities FAT 71, FAT 90, FAT 112 or FAT 140 should be specified for the joint as follows, according to the required fatigue strength (see ISO 10721-1):

Quality	**Required fatigue strength at 2×10^6 cycles**
FAT 71	57 N/mm^2 to 71 N/mm^2
FAT 90	72 N/mm^2 to 90 N/mm^2
FAT 112	91 N/mm^2 to 112 N/mm^2
FAT 140	113 N/mm^2 to 140 N/mm^2

The required fatigue quality for the joint should be indicated on the drawing by marking the appropriate quality level at the joint concerned, together with an arrow indicating the direction of stress fluctuation, see Figure D.2. (It should be noted that different qualities may be needed in different directions in special cases.)

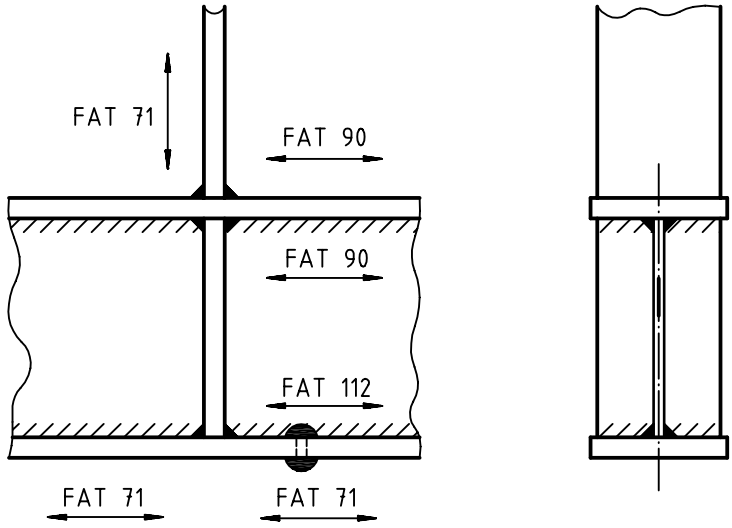


Figure D.2 — Method of identification of required fatigue class on the design drawings

D.5.3 Methods of inspection

Visual inspection, magnetic particle inspection and ultrasonic examination should be carried out in accordance with the appropriate national specifications.

Radiography should be in accordance with ISO 1106.

D.5.4 Testing of welding for cast steel

The testing of welding for cast steel should comply with the requirements of the appropriate national standard.

D.5.5 Stud shear connectors

Stud shear connectors should be subjected to the following tests:

a) Trial test studs/welding

At the start of each shift and change of operator/equipment, every stud should be tested by bending statically through an angle of 30° until two successive studs have demonstrated a full 360° flash and the weld shows no sign of cracking.

b) Production test

The following studs should be tested by bending through an angle of 15°, and the weld should show no signs of cracking:

i) all studs not showing a full 360° flash, so that the area of no flash is subject to tension;

ii) 2 % of all remaining studs as selected by the engineer. (where some or all the studs fail then a further 2 % shall be tested. If more than 0,25 % of the tested studs fail, further tests shall be carried out to identify the cause of the failure with a view to re-welding studs in a particular area or those welded by a particular operator/piece of equipment);

iii) any other studs directed by the inspection authority.

Bibliography

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[4] ISO 3088, *Welding requirements — Factors to be considered in specifying requirements for fusion welded joints in steel (technical influencing factors).*

[5] ISO 3834, *Welding — Factors to be considered when assessing firms using welding as a prime means of fabrication.*

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