BRITISH STANDARD

BS EN
1090-2:2008

Execution of steel structures and aluminium structures

Part 2: Technical requirements for the execution of steel structures

ICS 91.080.10

BSI
British Standards

National Foreword

This British Standard is the UK implementation of BS EN 1090-2:2008. It supersedes DD ENV 1090-1:1998, DD ENV 1090-4:2001, DD ENV 1090-6:2001 which are withdrawn, and BS 5400- 6:1999, BS 5950-2:2001 which will be withdrawn on March 2010.

The UK participation in its preparation was entrusted to Technical Committee B/521 Execution of steel structures, with the assistance of B/525/10 Bridges.

A list of organizations represented on this committee can be obtained on request to its secretary.

Additional information

BSI, as a member of CEN, is obliged to publish EN 1090-2:2008 as a British Standard. However, attention is drawn to the fact that during the development of this European Standard, the UK committee voted against its approval as a European Standard.

The reason for the UK committee vote was because of concerns about possible misspecification in terms of execution classes and weld quality levels in particular. If realized, these concerns about the range and the basis of some of the choices could lead either to under-specification and inadequate safety or to over-specification and possible barriers to trade. These issues are described more fully below, together with suggestions that should avoid these risks.

This standard gives the technical requirements for the execution (fabrication and erection) of steel structures and is a supporting standard for the harmonized standard BS EN 1090-1, *Execution of steel structures and aluminium structures – Part 1: Requirements for conformity assessment of structural components*. Conformity assessment to BS EN 1090-1 requires that the manufacturer operates a certified factory production control system. The quality management requirements for factory production control include, for instance, levels of traceability and welding quality management which are defined by reference to BS EN 1090-2.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 December 2008

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Amendments/corrigenda issued since publication

Date	Comments

This standard supersedes several existing standards and hence has a very wide scope. Therefore, it requires specifiers to make a series of project- or application-specific decisions before execution commences on each part of the works. Annex A itemizes the additional and optional information required.

Execution classes

This standard introduces the concept of execution class (EXC) as a classified set of requirements specified for the execution of the works as a whole, of an individual component, or of a detail of a component. Annex A.3 itemizes those requirements in the standard which depend on the choice of execution class.

It is a design decision for the specifier to select the execution class required for the works as a whole, an individual component, or a particular detail of a component. Annex B of BS EN 1090-2 provides some informative guidance on the factors that might be relevant to that decision. The primary reason to differentiate is to provide a level of reliability against failure or malfunction of the structure/component/detail that is matched to the consequences (see BS EN 1990, *Eurocode – Basis of structural design*, for further information). Hence, execution class is widely used in this standard as a reliability differentiator for providing choice of quality, testing and qualification requirements, although the relationship between this new differentiator and those recommended by BS EN 1990 is not fully defined.

Annex B of BS EN 1090-2 recommends that the choice of execution class should also depend on the 'service category' (SC) that characterizes a component in terms of the circumstances of its designed use, and the 'production category' (PC) that characterizes a component in terms of the methods used for its execution. These latter two types of category imply that, for a given structure/component/detail, the execution class specified should be increased in line with more onerous demands in service and/or if it is more difficult to produce.

From Annex B it appears likely that most steel structures in the UK will include components in both PC1 and PC2, but most will be SC1 unless they are designed for fatigue actions (in which case they will be SC2). Thus, as a default basis, EXC2 could be specified for structures/components/details used in buildings, and EXC3 could be specified for structures/components/details used in bridges.

Weld quality levels

For structures/components/details designed for fatigue additional requirements should be adopted because the simple choice between design for quasi-static (SC1) and fatigue (SC2) applications does not sufficiently discriminate the required weld quality levels in terms of fatigue classes.

In these circumstances, as the choice of appropriate requirements requires a level of design and construction knowledge that many potential users of this standard may not possess, reference should be made to the advice given in PD 6695-1-9, *Recommendations for the design of structures to BS EN 1993-1-9*, which explains the relationship between design and execution with respect to fatigue classes (FAT classes), and PD 6705-2, *Recommendations for the execution of steel bridges to BS EN 1090-2*, which gives acceptance criteria for welds designed for fatigue. These acceptance criteria have been developed for structural welds on a fitness-for-purpose basis and are consistent with those used in the British Standards that are superseded by BS EN 1090-2.

BS EN 1090-2 relates the execution classes to weld quality levels in BS EN ISO 5817, *Welding – Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) – Quality levels for imperfections*, as follows:

- EXC1: Quality level D;
- EXC2: Quality level C generally;
- EXC3: Quality level B (i.e. as required for welder qualification tests and welding procedure qualification records);
- EXC4: Quality level B+.

These levels may generally be appropriate to establish, prequalify and certificate the routine quality level of the manufacturer's welding operations. However, although EXC4 can be used to specify the extent of supplementary non-destructive testing, the associated quality level B+ is not practically achievable in routine production as it requires the manufacturer to demonstrate a capability of meeting a quality level which is more stringent than that for which the manufacturer's welders and welding procedures are qualified. Thus, if a quality level of B or higher is required, it is more practical to specify this for each relevant joint detail and not for routine production, using the acceptance criteria given in PD 6705-2 for evaluating imperfections on an individual basis, as permitted by BS EN 1090-2.

Tolerances

BS EN 1090-2 is more complicated than the British Standards that it supersedes in its approach to specifying permitted geometrical deviations as systems of tolerances. Three types of geometrical tolerance are defined:

1. essential tolerances that are essential for the mechanical resistance and stability of the completed structure and which are used to support conformity assessment to BS EN 1090-1;
2. functional tolerances required to fulfil other criteria such as fit-up and appearance;
3. special tolerances that may be specified for project-specific reasons, and which would need to be clearly defined in the execution specification.

Functional tolerances are defined for two classes, of which the less onerous tolerance class 1 is the default specification for routine execution. Tolerance class 2 is likely to require special and more expensive measures in fabrication and erection.

As an alternative, the standard allows BS EN ISO 13920, *Welding – General tolerances for welded constructions – Dimensions for lengths and angles – Shape and position*, to be used as the basis for specifying functional tolerances. BS EN ISO 13920 is suitable for those weldments and more heavily welded structural components where potential distortion from welding is the dominant factor in determining the dimensions and shape of the completed component and its fit-up to other components. BS EN 1090-2 selects the class relevant to the function of structural components from the four tolerance classes defined in BS EN ISO 13920.

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

Compliance with a British Standard cannot confer immunity from legal obligations.

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1090-2

July 2008

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Supersedes ENV 1090-1:1996, ENV 1090-2:1998, ENV 1090-3:1997, ENV 1090-4:1997, ENV 1090-5:1998, ENV 1090-6:2000

English Version

Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures

Exécution des structures en acier et des structures en aluminium - Partie 2: Exigences techniques pour les structures en acier

Ausführung von Stahltragwerken und Aluminiumtragwerken - Teil 2: Technische Regeln für die Ausführung von Stahltragwerken

This European Standard was approved by CEN on 11 April 2008.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This document (EN 1090-2:2008) has been prepared by Technical Committee CEN/TC 135 “Execution of steel structures and aluminium structures”, the secretariat of which is held by SN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2009, and conflicting national standards shall be withdrawn at the latest by March 2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes ENV 1090-1:1996, ENV 1090-2:1998, ENV 1090-3:1997, ENV 1090-4:1997, ENV 1090-5:1998 and ENV 1090-6:2000.

EN 1090, *Execution of steel structures and aluminium structures* consists of the following parts:

Part 1: Requirements for conformity assessment of structural components

Part 2: Technical requirements for steel structures

Part 3: Technical requirements for aluminium structures

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This European Standard specifies requirements for execution of steel structures, in order to ensure adequate levels of mechanical resistance and stability, serviceability and durability.

This European Standard specifies requirements for execution of steel structures in particular those that are designed according to all parts of EN 1993 and the steel parts of composite steel and concrete structures designed according to all parts of EN 1994.

This European Standard presupposes that the work is carried out with the necessary skill and adequate equipment and resources to perform the work in accordance with the execution specification and the requirements of this European Standard.

1 Scope

This European Standard specifies requirements for execution of structural steelwork as structures or as manufactured components, produced from:

— hot rolled, structural steel products up to and including grade S690;

— cold formed components and sheeting up to and including grades S700 for stainless steels and including S690 for carbon steels;

— hot finished and cold formed austenitic, austenitic-ferritic and ferritic stainless steel products;

— hot finished and cold formed structural hollow sections, including standard range and custom-made rolled products and hollow sections manufactured by welding.

This European Standard may also be used for structural steel grades up to and including S960, provided that conditions for execution are verified against reliability criteria and any necessary additional requirements are specified.

This European Standard specifies requirements independent of the type and shape of the steel structure (e.g. buildings, bridges, plated or latticed components) including structures subjected to fatigue or seismic actions. The requirements are expressed in terms of execution classes

This European Standard applies to structures designed according to the relevant part of EN 1993.

This European Standard applies to structural components and sheeting as defined in EN 1993-1-3.

This European Standard applies to steel components in composite steel and concrete structures designed according to the relevant part of EN 1994.

This European Standard may be used for structures designed according to other design rules provided that conditions for execution comply with them and any necessary additional requirements are specified.

This European Standard does not cover requirements for watertightness or air permeability resistance of sheeting.

2 Normative references

2.1 General

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

2.2 Constituent products

2.2.1 Steels

EN 10017, *Steel rod for drawing and/or cold rolling — Dimensions and tolerances*

EN 10021, *General technical delivery conditions for steel products*

EN 10024, *Hot rolled taper flange I sections — Tolerances on shape and dimensions*

EN 10025-1:2004, *Hot rolled products of structural steels — Part 1: General technical delivery conditions*

EN 10025-2, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

EN 10025-3, *Hot rolled products of structural steels — Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels*

EN 10025-4, *Hot rolled products of structural steels — Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels*

EN 10025-5, *Hot rolled products of structural steels — Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance*

EN 10025-6, *Hot rolled products of structural steels — Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition*

EN 10029, *Hot rolled steel plates 3 mm thick or above — Tolerances on dimensions, shape and mass*

EN 10034, *Structural steel I and H sections — Tolerances on shape and dimensions*

EN 10048, *Hot rolled narr ow steel strip — Tolerances on dimensions and shape*

EN 10051, *Continuously hot-rolled uncoated plate, sheet and strip of non-alloy and alloy steels — Tolerances on dimensions and shape*

EN 10055, *Hot rolled steel equal flange tees with radiused root and toes — Dimensions and tolerances on shape and dimensions*

EN 10056-1, *Structural steel equal and unequal leg angles — Part 1: Dimensions*

EN 10056-2, *Structural steel equal and unequal leg angles — Part 2: Tolerances on shape and dimensions*

EN 10058, *Hot rolled flat steel bars for general purpose — Dimensions and tolerances on shape and dimensions*

EN 10059, *Hot rolled square steel bars for general purposes — Dimensions and tolerances on shape and dimensions*

EN 10060, *Hot rolled round steel bars for general purposes — Dimensions and tolerances on shape and dimensions*

EN 10061, *Hot rolled hexagon steel bars for general purposes — Dimensions and tolerances on shape and dimensions*

EN 10080, *Steel for the reinforcement of concrete — Weldable reinforcing steel — General*

EN 10088-1, *Stainless steels — Part 1: List of stainless steels*

EN 10088-2:2005, *Stainless steels — Part 2: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes*

EN 10088-3:2005, *Stainless steels — Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes*

EN 10131, *Cold rolled uncoated and zinc or zinc-nickel electrolytically coated low carbon and high yield strength steel flat products for cold forming — Tolerances on dimensions and shape*

EN 10139, *Cold rolled uncoated mild steel narrow strip for cold forming — Technical delivery conditions*

EN 10140, *Cold rolled narrow steel strip — Tolerances on dimensions and shape*

EN 10143, *Continuously hot-dip coated steel sheet and strip — Tolerances on dimensions and shape*

EN 10149-1, *Hot-rolled flat products made of high yield strength steels for cold forming — Part 1: General delivery conditions*

EN 10149-2, *Hot-rolled flat products made of high yield strength steels for cold forming — Part 2: Delivery conditions for thermomechanically rolled steels*

EN 10149-3, *Hot-rolled flat products made of high yield strength steels for cold forming — Part 3: Delivery conditions for normalized or normalized rolled steels*

EN 10160, *Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)*

EN 10163-2, *Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections — Part 2: Plate and wide flats*

EN 10163-3, *Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections — Part 3: Sections*

EN 10164, *Steel products with improved deformation properties perpendicular to the surface of the product — Technical delivery conditions*

EN 10169-1, *Continuously organic coated (coil coated) steel flat products — Part 1: General information (definitions, materials, tolerances, test methods)*

EN 10169-2, *Continuously organic coated (coil coated) steel flat products — Part 2: Products for building exterior applications*

EN 10169-3, *Continuously organic coated (coil coated) steel flat products — Part 3: Products for building interior applications*

EN 10204, *Metallic products — Types of inspection documents*

EN 10210-1, *Hot finished structural hollow sections of non-alloy and fine grain steels — Part 1: Technical delivery conditions*

EN 10210-2, *Hot finished structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimension and sectional properties*

EN 10219-1, *Cold formed welded structural hollow sections of non-alloy and fine grain steels — Part 1: Technical delivery conditions*

EN 10219-2, *Cold formed welded structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimensions and sectional properties*

EN 10268, *Cold rolled steel flat products with high yield strength for cold forming — Technical delivery conditions*

EN 10279, *Hot rolled steel channels — Tolerances on shape, dimensions and mass*

EN 10292, *Continuously hot-dip coated strip and sheet of steels with high yield strength for cold forming — Technical delivery conditions*

EN 10296-2:2005, *Welded circular steel tubes for mechanical and general engineering purposes — Technical delivery conditions — Part 2: Stainless steel*

EN 10297-2:2005, *Seamless circular steel tubes for mechanical and general engineering purposes — Technical delivery conditions — Part 2: Stainless steel*

EN 10326, *Continuously hot-dip coated strip and sheet structural steels — Technical delivery conditions*

EN 10327, *Continuously hot-dip coated strip and sheet of low carbon steels for cold forming — Technical delivery conditions*

EN ISO 1127, *Stainless steel tubes — Dimensions, tolerances and conventional masses per unit length (ISO 1127:1992)*

EN ISO 9445, *Continuously cold-rolled stainless steel narrow strip, wide strip, plate/sheet and cut lengths — Tolerances on dimensions and form (ISO 9445:2002)*

ISO 4997, *Cold-reduced carbon steel sheet of structural quality*

2.2.2 Steel castings

EN 10340:2007, *Steel castings for structural uses*

2.2.3 Welding consumables

EN 756, *Welding consumables — Solid wires, solid wire-flux and tubular cored electrode-flux combinations for submerged arc welding of non alloy and fine grain steels — Classification*

EN 757, *Welding consumables — Covered electrodes for manual metal arc welding of high strength steels — Classification*

EN 760, *Welding consumables — Fluxes for submerged arc welding — Classification*

EN 1600, *Welding consumables — Covered electrodes for manual metal arc welding of stainless and heat resisting steels — Classification*

EN 13479, *Welding consumables — General product standard for filler metals and fluxes for fusion welding of metallic materials*

EN 14295, *Welding consumables — Wire and tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels — Classification*

EN ISO 636, *Welding consumables — Rods, wires and deposits for tungsten inert gas welding of non alloy and fine grain steels — Classification (ISO 636:2004)*

EN ISO 2560, *Welding consumables — Covered electrodes for manual metal arc welding of non-alloy and fine grain steels — Classification (ISO 2560:2002)*

EN ISO 13918, *Welding — Studs and ceramic ferrules for arc stud welding (ISO 13918:2008)*

EN ISO 14175, *Welding consumables — Gases and gas mixtures for fusion welding and allied processes (ISO 14175:2008)*

EN ISO 14341, *Welding consumables — Wire electrodes and deposits for gas shielded metal arc welding of non alloy and fine grain steels — Classification (ISO 14341:2002)*

EN ISO 14343, *Welding consumables — Wires electrodes, strip electrodes, wires and rods for fusion welding of stainless and heat resisting steels — Classification (ISO 14343:2002 and ISO 14343:2002/Amd1:2006)*

EN ISO 16834, *Welding consumables — Wire electrodes, wires, rods and deposits for gas-shielded arc welding of high strength steels — Classification (ISO 16834:2006)*

EN ISO 17632, *Welding consumables — Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non alloy and fine grain steels — Classification (ISO 17632:2004)*

EN ISO 17633, *Welding consumables — Tubular cored electrodes and rods for gas shielded and non-gas shielded metal arc welding of stainless and heat-resisting steels — Classification (ISO 17633:2004)*

EN ISO 18276, *Welding consumables — Tubular cored electrodes for gas-shielded and non-gas-shielded metal arc welding of high-strength steels — Classification (ISO 18276:2005)*

2.2.4 Mechanical fasteners

EN 14399-1, *High-strength structural bolting assemblies for preloading — Part 1: General requirements*

EN 14399-2, *High-strength structural bolting assemblies for preloading — Part 2: Suitability test for preloading*

EN 14399-3, *High-strength structural bolting assemblies for preloading — Part 3: System HR — Hexagon bolt and nut assemblies*

EN 14399-4:2005, *High-strength structural bolting assemblies for preloading — Part 4: System HV — Hexagon bolt and nut assemblies*

EN 14399-5, *High-strength structural bolting assemblies for preloading — Part 5: Plain washers*

EN 14399-6, *High-strength structural bolting assemblies for preloading — Part 6: Plain chamfered washers*

EN 14399-7, *High-strength structural bolting assemblies for preloading — Part 7: System HR — Countersunk head bolts and nut assemblies*

EN 14399-8, *High-strength structural bolting assemblies for preloading — Part 8: System HV — Hexagon fit bolt and nut assemblies*

prEN 14399-9, *High-strength structural bolting assemblies for preloading — Part 9: System HR or HV — Bolt and nut assemblies with direct tension indicators*

prEN 14399-10, *High-strength structural bolting assemblies for preloading — Part 10: System HRC — Bolt and nut assemblies with calibrated preload*

EN 15048-1, *Non preloaded structural bolting assemblies — Part 1: General requirements*

EN 20898-2, *Mechanical properties of fasteners — Part 2: Nuts with specified proof load values — Coarse thread (ISO 898-2:1992)*

EN ISO 898-1, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs (ISO 898-1:1999)*

EN ISO 1479, *Hexagon head tapping screws (ISO 1479:1983)*

EN ISO 1481, *Slotted pan head tapping screws (ISO 1481:1983)*

EN ISO 3506-1, *Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 1: Bolts, screws and studs (ISO 3506-1:1997)*

EN ISO 3506-2, *Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 2: Nuts (ISO 3506-2:1997)*

EN ISO 6789, *Assembly tools for screws and nuts — Hand torque tools — Requirements and test methods for design conformance testing, quality conformance testing and recalibration procedure (ISO 6789:2003)*

EN ISO 7049, *Cross recessed pan head tapping screws (ISO 7049:1983)*

EN ISO 10684, *Fasteners — Hot dip galvanized coatings (ISO 10684:2004)*

EN ISO 15480, *Hexagon washer head drilling screws with tapping screw thread (ISO 15480:1999)*

EN ISO 15976, *Closed end blind rivets with break pull mandrel and protruding head — St/St (ISO 15976:2002)*

EN ISO 15979, *Open end blind rivets with break pull mandrel and protruding head — St/St (ISO 15979:2002)*

EN ISO 15980, *Open end blind rivets with break pull mandrel and countersunk head — St/St (ISO 15980:2002)*

EN ISO 15983, *Open end blind rivets with break pull mandrel and protruding head — A2/A2 (ISO 15983:2002)*

EN ISO 15984, *Open end blind rivets with break pull mandrel and countersunk head — A2/A2 (ISO 15984:2002)*

ISO 10509, *Hexagon flange head tapping screws*

2.2.5 High strength cables

prEN 10138-3, *Prestressing steels — Part 3: Strand*

EN 10244-2, *Steel wire and wire products — Non-ferrous metallic coatings on steel wire — Part 2: Zinc or zinc alloy coatings*

EN 10264-3, *Steel wire and wire products — Steel wire for ropes — Part 3: Round and shaped non alloyed steel wire for high duty applications*

EN 10264-4, *Steel wire and wire products — Steel wire for ropes — Part 4: Stainless steel wire*

EN 12385-1, *Steel wire ropes — Safety — Part 1: General requirements*

EN 12385-10, *Steel wire ropes — Safety — Part 10: Spiral ropes for general structural applications*

EN 13411-4, *Terminations for steel wire ropes — Safety — Part 4: Metal and resin socketing*

2.2.6 Structural bearings

EN 1337-2, *Structural bearings — Part 2: Sliding elements*

EN 1337-3, *Structural bearings — Part 3: Elastomeric bearings*

EN 1337-4, *Structural bearings — Part 4: Roller bearings*

EN 1337-5, *Structural bearings — Part 5: Pot bearings*

EN 1337-6, *Structural bearings — Part 6: Rocker bearings*

EN 1337-7, *Structural bearings — Part 7: Spherical and cylindrical PTFE bearings*

EN 1337-8, *Structural bearings — Part 8: Guide bearings and restraint bearings*

2.3 Preparation

EN ISO 9013, *Thermal cutting — Classification of thermal cuts — Geometrical product specification and quality tolerances (ISO 9013:2002)*

ISO 286-2, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts*

CEN/TR 10347, *Guidance for forming of structural steels in processing*

2.4 Welding

EN 287-1, *Qualification test of welders — Fusion welding — Part 1: Steels*

EN 1011-1:1998, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding*

EN 1011-2:2001, *Welding — Recommendations for welding of metallic materials — Part 2: Arc welding of ferritic steels*

EN 1011-3, *Welding — Recommendations for welding of metallic materials — Part 3: Arc welding of stainless steels*

EN 1418, *Welding personnel — Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials*

EN ISO 3834 (all parts), *Quality requirements for fusion welding of metallic materials (ISO 3834:2005)*

EN ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers (ISO 4063:1998)*

EN ISO 5817, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections (ISO 5817:2003, corrected version:2005, including Technical Corrigendum 1:2006)*

EN ISO 9692-1, *Welding and allied processes — Recommendations for joint preparation — Part 1: Manual metal-arc welding, gas-shielded metal-arc welding, gas welding, TIG welding and beam welding of steels (ISO 9692-1:2003)*

EN ISO 9692-2, *Welding and allied processes — Joint preparation — Part 2: Submerged arc welding of steels (ISO 9692-2:1998)*

EN ISO 13916, *Welding — Guidance on the measurement of preheating temperature, interpass temperature and preheat maintenance temperature (ISO 13916:1996)*

EN ISO 14373, *Resistance welding — Procedure for spot welding of uncoated and coated low carbon steels (ISO 14373:2006)*

EN ISO 14554 (all parts), *Quality requirements for welding — Resistance welding of metallic materials (ISO 14544-1:2000)*

EN ISO 14555, *Welding — Arc stud welding of metallic materials (ISO 14555:2006)*

EN ISO 14731, *Welding coordination — Tasks and responsibilities (ISO 14731:2006)*

EN ISO 15609-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding (ISO 15609-1:2004)*

EN ISO 15609-4, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 4: Laser beam welding (ISO 15609-4:2004)*

EN ISO 15609-5, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 5: Resistance welding (ISO 15609-5:2004)*

EN ISO 15610, *Specification and qualification of welding procedures for metallic materials — Qualification based on tested welding consumables (ISO 15610:2003)*

EN ISO 15611, *Specification and qualification of welding procedures for metallic materials — Qualification based on previous welding experience (ISO 15611:2003)*

EN ISO 15612, *Specification and qualification of welding procedures for metallic materials — Qualification by adoption of a standard welding procedure (ISO 15612:2004)*

EN ISO 15613, *Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test (ISO 15613:2004)*

EN ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2004)*

EN ISO 15614-11, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 11: Electron and laser beam welding (ISO 15614-11:2002)*

EN ISO 15614-13, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 13: Resistance butt and flash welding (ISO 15614-13:2005)*

EN ISO 15620, *Welding — Friction welding of metallic materials (ISO 15620:2000)*

EN ISO 16432, *Resistance welding — Procedure for projection welding of uncoated and coated low carbon steels using embossed projection(s) (ISO 16432:2006)*

EN ISO 16433, *Resistance welding — Procedure for seam welding of uncoated and coated low carbon steels (ISO 16433:2006)*

2.5 Testing

EN 473, *Non destructive testing — Qualification and certification of NDT personnel — General principles*

EN 571-1, *Non destructive testing — Penetrant testing — Part 1: General principles*

EN 970, *Non-destructive examination of fusion welds — Visual examination*

EN 1290, *Non-destructive examination of welds — Magnetic particle examination of welds*

EN 1435, *Non-destructive testing of welds — Radiographic testing of welded joints*

EN 1713, *Non-destructive testing of welds — Ultrasonic testing — Characterization of indications in welds*

EN 1714, *Non-destructive testing of welds — Ultrasonic testing of welded joints*

EN 10160, *Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)*

EN 12062:1997, *Non-destructive examination of welds — General rules for metallic materials*

EN ISO 6507 (all parts), *Metallic materials — Vickers hardness test (ISO 6507:2005)*

EN ISO 9018, *Destructive tests on welds in metallic materials — Tensile test on cruciform and lapped joints (ISO 9018:2003)*

EN ISO 10447, *Resistance welding - Peel and chisel testing of resistance spot and projection welds (ISO 10447:2006)*

2.6 Erection

EN 1337-11, *Structural bearings — Part 11: Transport, storage and installation*

ISO 4463-1, *Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization, measuring procedures, acceptance criteria*

ISO 7976-1, *Tolerances for building — Methods of measurement of buildings and building products — Part 1: Methods and instruments*

ISO 7976-2, *Tolerances for building — Methods of measurement of buildings and building products — Part 2: Position of measuring points*

ISO 17123 (all parts), *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments*

2.7 Corrosion protection

EN 14616, *Thermal spraying — Recommendations for thermal spraying*

EN 15311, *Thermal spraying — Components with thermally sprayed coatings — Technical supply conditions*

EN ISO 1461:1999, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods (ISO 1461:1999)*

EN ISO 2063, *Thermal spraying — Metallic and other inorganic coatings — Zinc, aluminium and their alloys (ISO 2063:2005)*

EN ISO 2808, *Paints and varnishes — Determination of film thickness (ISO 2808:2007)*

EN ISO 8501 (all parts), *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness*

EN 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 8503-1:1988)*

EN 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 8503-2:1988)*

EN ISO 12944 (all parts), *Paints and varnishes — Corrosion protection of steel structures by protective paint systems (ISO 12944:1998)*

EN ISO 14713, *Protection against corrosion of iron and steel in structures — Zinc and aluminium coatings — Guidelines (ISO 14713:1999)*

ISO 19840, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces*

2.8 Tolerances

EN ISO 13920, *Welding — General tolerances for welded constructions — Dimensions for lengths and angles — Shape and position (ISO 13920:1996)*

2.9 Miscellaneous

EN 508-1, *Roofing products from metal sheet — Specification for self-supporting products of steel, aluminium or stainless steel sheet — Part 1: Steel*

EN 508-3, *Roofing products from metal sheet — Specification for self-supporting products of steel, aluminium or stainless steel sheet — Part 3: Stainless steel*

EN 1993-1-6, *Eurocode 3: Design of steel structures — Part 1-6: Strength and Stability of Shell Structures*

EN 1993-1-8, *Eurocode 3: Design of steel structures — Part 1-8: Design of joints*

prEN 13670, *Execution of concrete structures*

ISO 2859-5, *Sampling procedures for inspection by attributes — Part 5: System of sequential sampling plans indexed by acceptance quality limit (ALQ) for lot-by-lot inspection*

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

3.1
construction works
everything that is constructed or results from construction operations. This term covers both building and civil engineering works. It refers to the complete construction comprising both structural and non-structural components

3.2
works
parts of construction works that are structural steelwork

3.3
structural steelwork
steel structures or manufactured steel components used in construction works

3.4
constructor
person or organization executing the works (the supplier in EN ISO 9000)

3.5
structure
see EN 1990

3.6
manufacturing
all activities required to produce and deliver a component. As relevant, this comprises e.g. procurement, preparation and assembly, welding, mechanical fastening, transportation, surface treatment and the inspection and documentation thereof

3.7
execution
all activities performed for the physical completion of the works, i.e. procurement, fabrication, welding, mechanical fastening, transportation, erection, surface treatment and the inspection and documentation thereof

3.7.1
execution specification
set of documents covering technical data and requirements for a particular steel structure including those specified to supplement and qualify the rules of this European Standard

NOTE 1 Execution specification includes requirements where this European Standard identifies items to be specified.

NOTE 2 Execution specification can be seen as the complete set of requirements for manufacture and installation of structural steel components with the manufacturing requirements given in a set of component specifications according to prEN 1090-1.

3.7.2
execution class
classified set of requirements specified for the execution of the works as a whole, of an individual component or of a detail of a component

3.8
service category
category that characterises a component in terms of the circumstances of its use

3.9
production category
category that characterises a component in terms of the methods used for its execution

3.10
constituent product
material and product used for manufacturing a component and which remains as part of it, e.g. structural steel product, stainless steel product, mechanical fastener, welding consumable

3.11
component
part of a steel structure, which may itself be an assembly of several smaller components

3.11.1
cold formed component
see EN 10079 and EN 10131

3.12
preparation
all activities performed on the constituent steel products to produce the parts ready for assembly and inclusion in components. As relevant, this comprises e.g. identification, handling and storage, cutting, shaping and holing.

3.13
design basis method of erection
outline of a method of erection upon which the design of the structure is based (also known as the design erection sequence)

3.13.1
erection method statement
documentation describing the procedures to be used to erect a structure

3.14
nonconformity
see EN ISO 9000

3.15
additional NDT (non destructive testing)
NDT technique which is additional to visual examination, e.g. magnetic particle, penetrant, eddy current, ultrasonic or radiographic testing

3.16
tolerance
see ISO 1803

3.16.1
essential tolerance
basic limits for a geometrical tolerance necessary to satisfy the design assumptions for structures in terms of mechanical resistance and stability

3.16.2
functional tolerance
geometrical tolerance which might be required to meet a function other than mechanical resistance and stability, e.g appearance or fit up

3.16.3
special tolerance
geometrical tolerance which is not covered by the tabulated types or values of tolerances given in this European Standard, and which needs to be specified in a particular case

3.16.4
manufacturing tolerance
permitted range in the size of a dimension of a component resulting from component manufacture

4 Specifications and documentation

4.1 Execution Specification

4.1.1 General

The necessary information and technical requirements for execution of each part of the works shall be agreed and complete before commencement of execution of that part of the works. There shall be procedures for making alterations to previously agreed execution specification. Execution specification shall consider such of the following items as are relevant:

a) additional information, as listed in A.1;

b) options, as listed in A.2;

c) execution classes, see 4.1.2;

d) preparation grades, see 4.1.3;

e) tolerance classes, see 4.1.4;

f) technical requirements regarding the safety of the works, see 4.2.3 and 9.2.

4.1.2 Execution classes

Four execution classes 1 to 4, denoted EXC1 to EXC4, are given, for which requirement strictness increases from EXC1 to EXC4.

Execution classes may apply to the whole structure or to a part of the structure or to specific details. A structure can include several execution classes. A detail or group of details will normally be ascribed one execution class. However, the choice of an execution class does not necessarily have to be the same for all requirements.

If no execution class is specified EXC2 shall apply.

The list of requirements related to execution classes is given in A.3.

Guidance for the choice of execution classes is given in Annex B.

NOTE The choice of execution classes is related to production categories and service categories, with links to consequence classes as defined in Annex B of EN 1990:2002.

4.1.3 Preparation grades

Three preparation grades, denoted P1 to P3 according to ISO 8501-3, are given, for which requirement strictness increases from P1 to P3.

NOTE Preparation grades are related to the expected life of the corrosion protection and corrosivity category as defined in Clause 10.

Preparation grades may apply to the whole structure or to a part of the structure or to specific details. A structure can include several preparation grades. A detail or group of details will normally be ascribed one preparation grade.

4.1.4 Geometrical tolerances

Two types of geometrical tolerances are defined in 11.1:

a) essential tolerances;

b) functional tolerances, with two classes for which requirement strictness increases from class 1 to class 2.

4.2 Constructor's documentation

4.2.1 Quality documentation

The following points shall be documented for EXC2, EXC3 and EXC4:

a) the allocation of tasks and authority during the various phases of the project;

b) the procedures, methods and work instructions to be applied;

c) an inspection plan specific to the works;

d) a procedure for handling changes and modifications;

e) a procedure for handling of nonconformities, requests for concessions and quality disputes;

f) any hold points or requirement to witness inspections or tests, and any consequent access requirements.

4.2.2 Quality plan

It shall be specified if a quality plan for execution of the works is required.

NOTE EN ISO 9000 gives the definition of a quality plan.

It shall include:

a) a general management document which shall address the following points:

1) review of specification requirements against process capabilities;

2) organisation chart and managerial staff responsible for each aspect of the execution;

3) principles and organisation arrangements for inspection including allocation of responsibilities for each inspection task;

b) quality documentation prior to execution as defined in 4.2.1. The documents shall be produced before execution of the construction step to which they relate;

c) execution records which are actual records of inspections and checks carried out, or demonstrate qualification or certification of implemented resources. Execution records related to a hold-point that affect continuation of execution shall be produced before the hold-point is released.

Annex C gives a check-list for the content of a quality plan recommended for the execution of structural steelwork with reference to the general guidelines in ISO 10005.

4.2.3 Safety of the erection works

Method statements giving detailed work instructions shall comply with the technical requirements relating to the safety of the erection works as given in 9.2 and 9.3.

4.2.4 Execution documentation

Sufficient documentation shall be prepared during execution and as a record of the as-built structure to demonstrate that the works have been carried out according to the execution specification.

5 Constituent products

5.1 General

Generally constituent products to be used for the execution of steel structures shall be selected from the relevant European Standards listed in the following clauses. If constituent products that are not covered by the standards listed are to be used, their properties shall be specified.

Definitions and requirements of EN 10021 shall apply together with those of the relevant European product standard.

5.2 Identification, inspection documents and traceability

The properties of supplied constituent products shall be documented in a way that enables them to be compared to the specified properties. Their conformity with the relevant product standard shall be checked in accordance with 12.2.

For metallic products, the inspection documents according to EN 10204 shall be as listed in Table 1.

Table 1 — Inspection documents for metallic products

Constituent product	Inspection documents
Structural steels (Tables 2 and 3)	according to Table B.1 of EN 10025-1:2004 [a b]
Stainless steels (Table 4)	3.1
Steel castings	according to Table B.1 of EN 10340:2007
Welding consumables (Table 5)	2.2
Structural bolting assemblies	2.1 [c]
Hot rivets	2.1 [c]
Self-tapping and self-drilling screws and blind rivets	2.1
Studs for arc studs welding	2.1 [c]
Expansion joints for bridges	3.1
High strength cables	3.1
Structural bearings	3.1

[a] For structural steel grade S355 JR or J0 inspection document 3.1 is required for EXC2, EXC3 and EXC4.

[b] EN 10025-1 requires that the elements included in the CEV formula shall be reported in the inspection document. The reporting of other added elements required by EN 10025-2 should include Al, Nb, and Ti.

[c] If a 3.1 certificate is required, this may be substituted by a manufacturing lot identification mark.

For EXC3 and EXC4, constituent products shall be traceable at all stages from receipt to hand over after incorporation in the works.

This traceability may be based on records for batches of product allocated to a common production process, unless traceability for each product is specified.

For EXC2, EXC3 and EXC4, if differing grades and/or qualities of constituent products are in circulation together, each item shall be designated with a mark that identifies its grade.

Methods of marking shall be in accordance with that for components given in 6.2.

If marking is required, unmarked constituent products shall be treated as non conforming product.

5.3 Structural steel products

5.3.1 General

Structural steel products shall conform to the requirements of the relevant European product standards as listed in Tables 2, 3 and 4, unless otherwise specified. Grades, qualities and, if appropriate, coating weights and finishes, shall be specified together with any required options permitted by the product standard, including those related to suitability for hot dip zinc-coating, if relevant.

Steel products to be used in the manufacture of cold formed components shall have properties that conform to the required suitability for cold forming process. Carbon steels suitable for cold forming are listed in Table 3.

Table 2 — Product standards for structural carbon steels

Products	Technical delivery requirements	Dimensions	Tolerances
I and H sections	EN 10025-1 and EN 10025-2 EN 10025-3 EN 10025-4 EN 10025-5 EN 10025-6 As relevant	Not available	EN 10034
Hot-rolled taper flange I sections		Not available	EN 10024
Channels		Not available	EN 10279
Equal and unequal leg angles		EN 10056-1	EN 10056-2
T Sections		EN 10055	EN 10055
Plates, flats, wide flats		Not applicable	EN 10029 EN 10051
Bars and rods		EN 10017, EN 10058, EN 10059, EN 10060, EN 10061	EN 10017, EN 10058, EN 10059, EN 10060, EN 10061
Hot finished hollow sections	EN 10210-1	EN 10210-2	EN 10210-2
Cold formed hollow sections	EN 10219-1	EN 10219-2	EN 10219-2
NOTE EN 10020 gives definitions and classifications of grades of steel. Steel designations by name and number are given in EN 10027-1 and -2 respectively.			

Table 3 —Product standards for sheet and strip suitable for cold forming

Products	Technical delivery requirements	Tolerances
Non-alloy structural steels	EN 10025-2	EN 10051
Weldable fine grain structural steels	EN 10025-3, EN 10025-4	EN 10051
High yield strength steels for cold forming	EN 10149-1, EN 10149-2, EN 10149-3, EN 10268	Not available
Cold reduced steels	ISO 4997	EN 10131
Continuously coated hot dip coated steels	EN 10292, EN 10326, EN 10327	EN 10143
Continuously organic coated steel flat products	EN 10169-2, EN 10169-3	EN 10169-1
Narrow strips	EN 10139	EN 10048 EN 10140

Table 4 — Product standards for stainless steels

Products	Technical delivery requirements	Tolerances
Sheets, plates and strips	EN 10088-2	EN 10029, EN 10048, EN 10051, EN ISO 9445
Tubes (welded)	EN 10296-2	EN ISO 1127
Tubes (seamless)	EN 10297-2	
Bars, rods and sections	EN 10088-3	EN 10017, EN 10058, EN 10059, EN 10060, EN 10061
NOTE Steel designations by name and number are given in EN 10088-1.		

5.3.2 Thickness tolerances

Thickness tolerances for structural steel plates shall be as follows in accordance with EN 10029, unless otherwise specified:

EXC4: Class B

For other structural and stainless steel products the thickness class A shall be used unless otherwhise specified.

5.3.3 Surface conditions

For carbon steels, surface condition requirements are as follows:

a) class A2 for plates and wide flats in accordance with the requirements of EN 10163-2;

b) class C1 for sections in accordance with the requirements of EN 10163-3. Execution specifications shall specify if imperfections such as cracks, shell and seams shall be repaired.

If more stringent surface conditions are required for plates in EXC3 and EXC4, they shall be specified.

For stainless steel the surface finish requirements shall be as follows:

a) sheet, plate and strip: in accordance with the requirements of EN 10088-2;

b) bars, rods and sections: in accordance with the requirements of EN 10088-3.

Additional requirements related to the following items: special restrictions on either surface imperfections or repair of surface defects by grinding in accordance with EN 10163, or with EN 10088 for stainless steel, shall be specified.

For other products the surface finish requirements shall be specified in terms of appropriate European or International specifications.

If the relevant specification does not adequately define decorative or specialist surface finishes, the finish shall be specified.

The surface condition of constituent products shall be such that the relevant requirements for surface preparation grade in accordance with 10.2 can be achieved.

5.3.4 Special properties

For EXC3 and EXC4, internal discontinuity quality class S1 of EN 10160 shall be specified for welded cruciform joints transmitting primary tensile stresses through the plate thickness on a band of width four times the thickness of the plate each side of the proposed attachment.

It shall be specified whether areas close to bearing diaphragms or stiffeners should be checked for the existence of internal discontinuities. In this case quality class S1 of EN 10160 shall apply to a band of flange or web plate of width 25 times the plate thickness each side of a bearing diaphragm or stiffener if attached by welding.

In addition, requirements related to the following items shall be specified if relevant:

a) testing on constituent products, other than stainless steels, to identify internal discontinuities or cracks in zones to be welded;

b) improved deformation properties perpendicular to the surface of constituent products, other than stainless steels, in accordance with EN 10164;

c) special delivery conditions of stainless steels, for example Pitting Resistance Equivalent (Nitrogen) (PRE(N)) or accelerated corrosion testing. The PRE(N) shall be given by (Cr + 3.3 Mo + 16 N), in which the elements are in percent by weight, unless otherwise specified;

d) processing conditions if constituent products are to be processed before delivery.

NOTE Heat treatment, cambering and bending are examples of such processes.

5.4 Steel castings

Steel castings shall conform to the requirements in EN 10340. Grades, qualities and, if appropriate, finishes shall be specified together with any required options permitted by the product standard.

5.5 Welding consumables

All welding consumables shall conform to the requirements to EN 13479 and the appropriate product standard as listed in Table 5.

Table 5 — Product standards for welding consumables

Welding consumables	Product standards
Shielding gases for arc welding and cutting	EN ISO 14175
Wire electrodes and deposits for gas-shielded metal arc welding of non-alloy and fine grain steels	EN ISO 14341
Solid wires, solid wire-flux and tubular cored electrode-flux combinations for submerged arc welding of non alloy and fine grain steels	EN 756
Covered electrodes for manual arc welding of high strength steels	EN 757
Tubular cored electrodes for metal arc welding with and without gas shield of non alloy and fine grain steels	EN ISO 17632
Fluxes for submerged arc welding	EN 760
Covered electrodes for manual arc welding of stainless and heat resisting steels	EN 1600
Rods, wires and deposits for tungsten inert gas welding of non alloy and fine grain steels	EN ISO 636
Covered electrodes for manual arc welding of non-alloy and fine grain steels	EN ISO 2560
Wires electrodes, wires and rods for arc welding of stainless and heat-resisting steels	EN ISO 14343
Wire electrodes, wires, rods and deposits for gas-shielded arc welding of high strength steels	EN ISO 16834
Wire and tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels	EN 14295
Tubular cored electrodes for metal arc welding with or without a gas shield of stainless and heat-resisting steels	EN ISO 17633
Tubular cored electrodes for gas shielded metal arc welding of high strength steels	EN ISO 18276

The type of welding consumables shall be appropriate to the welding process, the material to be welded and the welding procedure.

For steel grades higher than S355, the use of consumables and fluxes with medium-high basicity index is recommended for the welding processes: 111, 114, 121, 122, 136, 137 (see 7.3 for definition of welding processes).

If steel according to EN 10025-5 is to be welded, welding consumables shall be used which ensure that the completed welds have a weather resistance at least equivalent to the parent metal. Unless otherwise specified, one of the options given in Table 6 shall be used.

Table 6 — Welding consumables to be used with steels according to EN 10025-5

Process	Option 1	Option 2	Option3
111	Matching	2,5 % Ni	1 % Cr 0,5 % Mo
135	Matching	2,5 % Ni	1 % Cr 0,5 % Mo
121,122	Matching	2 % Ni	1 % Cr 0,5 % Mo
Matching: 0,5 % Cu and other alloy elements			
NOTE See also 7.5.10.			

For stainless steels, welding consumables which give weld deposits of at least equivalent corrosion resistance to the parent metal shall be used.

5.6 Mechanical fasteners

5.6.1 General

The corrosion resistance of the connectors, fasteners and sealing washers shall be comparable to that specified for the fastened components.

Hot dip galvanized coatings of fasteners shall conform to EN ISO 10684.

Protective coatings of components for mechanical fasteners shall comply with the requirements of the relevant product standard or, in the absence thereof, with the manufacturer's recommendation.

5.6.2 Terminology

In the text the following terms are used:

a) "washer" meaning: "plain or chamfered washer";

b) "assembly" meaning: "a bolt with a nut and washer(s) as necessary".

5.6.3 Structural bolting assemblies for non preloaded applications

Carbon and alloy steel and austenitic stainless steel structural bolting assemblies for non preloaded applications shall conform to EN 15048-1.

Assemblies according to EN 14399-1 may also be used for non preloaded applications.

Property classes of bolts and nuts and, if appropriate, surface finishes shall be specified together with any required options permitted by the product standard.

The mechanical properties shall be specified for:

a) carbon and alloy steel bolting assemblies with larger diameter than those specified in EN ISO 898-1 and EN 20898-2;

b) austenitic stainless steel bolting assemblies with larger diameter than those specified in EN ISO 3506-1 and EN ISO 3506-2;

c) austenitic-ferritic bolts.

Fasteners according to EN ISO 898-1 and EN 20898-2 shall not be used to join stainless steels according to EN 10088 unless otherwise specified. If insulation kits are to be used full details of their use shall be specified.

5.6.4 Structural bolting assemblies for preloading

High strength structural bolting assemblies for preloading include system HR, system HV and HRC bolts. They shall conform to the requirements in EN 14399-1 and in the appropriate European Standard as listed in Table 7.

Property classes of bolts and nuts and, if appropriate, surface finishes shall be specified together with any required options permitted by the product standard.

Table 7 — Product standards for high strength structural bolting assemblies for preloading

Bolts and nuts	Washers
EN 14399-3 EN 14399-4 EN 14399-7 EN 14399-8 prEN 14399-10	EN 14399-5 EN 14399-6

Stainless steel bolts shall not be used in preloaded applications unless otherwise specified. If used they shall be treated as special fasteners.

5.6.5 Direct tension indicators

Direct tension indicators and associated hardened nut face and bolt face washers shall be in accordance with prEN 14399-9.

Direct tension indicators shall not be used with weather resistant steels or stainless steels.

5.6.6 Weather resistant assemblies

Weather resistant assemblies shall be made of improved atmospheric corrosion resistance material the chemical composition of which shall be specified.

NOTE Type 3 Grade A fasteners to ASTM standard A325 would be suitable [48].

Their mechanical characteristics, performances and delivery conditions shall conform to the requirements in EN 14399-1 or EN 15048-1 as relevant.

5.6.7 Foundation bolts

The mechanical properties of foundation bolts shall be in accordance with EN ISO 898-1 or fabricated from hot-rolled steel conforming to EN 10025-2 to EN 10025-4. If specified, reinforcing steels may be used. In this case they shall conform to EN 10080 and the steel grade shall be specified.

5.6.8 Locking devices

If required the locking devices such as prevailing torque nuts or other types of bolt which effectively prevent loosening of the assembly if subjected to impact or significant vibration shall be specified.

Unless otherwise specified, products from EN ISO 2320, EN ISO 7040, EN ISO 7042, EN ISO 7719, EN ISO 10511, EN ISO 10512 and EN ISO 10513 may be used.

5.6.9 Taper washers

Taper washers shall comply with the relevant product standard.

5.6.10 Hot rivets

Hot rivets shall comply with the relevant product standard.

5.6.11 Fasteners for thin gauge components

Self-drilling screws shall comply with EN ISO 15480 and self-tapping screws with EN ISO 1481, EN ISO 7049, EN ISO 1479 or ISO 10509.

Blind rivets shall comply with EN ISO 15976, EN ISO 15979, EN ISO 15980, EN ISO 15983 or EN ISO 15984.

Cartridge fired pins, air driven pins shall be classified as special fasteners.

Mechanical fasteners for use in stressed skin applications shall be of a specified type for such application.

5.6.12 Special fasteners

Special fasteners are fasteners that are not covered by European or International Standards. They shall be specified, as well as any tests necessary.

NOTE The use of special fasteners is covered in 8.9.

Hexagon injection bolts shall be classified as special fasteners.

5.6.13 Delivery and identification

Fasteners according to 5.6.3 to 5.6.5 shall be delivered and identified in accordance with the requirements of the relevant product standard.

Fasteners according to 5.6.7 to 5.6.12 shall be delivered and identified as follows:

a) They shall be delivered in an appropriate durable packaging and labelled such that the content is readily identifiable.

b) Labelling or accompanying documentation should contain the following information in a legible and durable form:

— manufacturer’s identification and, if relevant, lot numbers;

— type of fastener and material and, if appropriate, its assembly;

— protective coating;

— dimensions in mm, as appropriate for nominal diameter and length, and if appropriate, washer diameter, thickness and effective compression range of elastomeric part;

— size of drill bit as appropriate;

— for screws: details of the limiting torque values;

— for cartridge fired and air driven pins: details of the firing charge and driving forces as appropriate.

c) Fasteners and any associated washers shall bear a durable manufacturer's identification mark.

5.7 Studs and shear connectors

Studs for arc stud welding including shear connectors for steel/concrete composite construction shall comply with the requirements of EN ISO 13918.

Shear connectors other than the stud type shall be classified as special fasteners and comply with 5.6.12.

5.8 Grouting materials

The grouting materials to be used shall be specified. It shall be cement based grout, special grout or fine concrete.

Cement based grout for use between steel bases or bearing plates and concrete foundations shall be as follows:

a) for nominal thickness not exceeding 25 mm: Neat Portland cement;

b) for nominal thickness between 25 and 50 mm: Fluid Portland cement mortar that is not leaner than 1:1 cement to fine aggregate;

c) for nominal thickness of 50 mm and above: Dry as possible Portland cement mortar that is not leaner than 1:2 cement to fine aggregate.

Special grouts include cement based grouts used with admixtures, expanding grout and resin based grout. Those with low shrinkage characteristics are recommended.

Special grout shall be accompanied by detailed instructions for use that are attested by the manufacturer.

Fine concrete shall only be used between steel bases or bearing plates and concrete foundations that have gaps with nominal thickness of 50 mm and above.

5.9 Expansion joints for bridges

Requirements for type and characteristics of expansion joints shall be specified.

5.10 High strength cables, rods and terminations

Wires for high strength cables shall be cold drawn or cold rolled steel wires and conform to the requirements of EN 10264-3 or EN 10264-4. The tensile strength grade and, if appropriate, coating class according to EN 10244-2 shall be specified.

Strands for high strength cables shall conform to the requirements of prEN 10138-3. The designation and class of the strand shall be specified.

Steel wire ropes shall conform to the requirements of EN 12385-1 and EN 12385-10. The minimum breaking load and diameter of the steel wire rope and, if appropriate, requirements related to corrosion protection shall be specified.

The filling material for the sockets shall conform to the requirements of EN 13411-4. It shall be selected taking into account service temperature and actions such that continued creeping of the loaded strand through the socket is prevented.

5.11 Structural bearings

Structural bearings shall comply with the requirements of EN 1337-2, EN 1337-3, EN 1337-4, EN 1337-5, EN 1337-6, EN 1337-7 or EN 1337-8 as relevant.

6 Preparation and assembly

6.1 General

This clause specifies the requirements for cutting, shaping, holing and assembly of constituent steel components for inclusion into components.

NOTE Welding and mechanical fastening are dealt with in Clauses 7 and 8.

Structural steelwork shall be fabricated considering the requirements in Clause 10 and within the tolerances specified in Clause 11.

Equipment used in the manufacturing process shall be maintained to ensure that use, wear and failure do not cause significant inconsistency in the manufacturing process.

6.2 Identification

At all stages of manufacturing each piece or package of similar pieces of steel components shall be identifiable by a suitable system. For EXC3 and EXC4 finished components shall be identified to inspection certificates.

Identification may be achieved as appropriate by batching or by the shape and the size of the component or by the use of durable and distinguishing marks applied in a way not producing damage. Chiselled notches are not permitted.

The following requirements apply to hard stamped, punched or drilled marks used for marking single components or packages of similar components, unless otherwise specified:

a) they are permitted only for steel grades up to and including S355;

b) they are not permitted for stainless steels;

c) they are not permitted on coated materials for cold-formed components;

d) they shall only be used in the specified areas where the marking method would not affect the fatigue life.

If the use of hard stamps, punched or drilled marks is not permitted, it shall be specified whether soft or low stress stamps may be used.

Soft or low stress stamps may be used for stainless steels unless otherwise specified.

Any zones where identification marks are not permitted or shall not be visible after completion shall be specified.

6.3 Handling and storage

Constituent products shall be handled and stored in conditions that are in accordance with product manufacturer's recommendations.

A constituent product shall not be used beyond a shelf life specified by its manufacturer. Products that have been handled or stored in a way or for a length of time that could have led to significant deterioration shall be checked before use to ensure that they still comply with the relevant product standard.

Structural steel components shall be packed, handled and transported in a safe manner, so that permanent deformation does not occur and surface damage is minimised. Handling and storage preventive measures specified in Table 8 shall be applied as appropriate.

Table 8 — List of handling and storage preventive measures

Lifting	
1	Protection of components from damage at the lifting points
2	Avoidance of single point lifting of long components by use of spreader beams as appropriate
3	Bundling together lightweight components particularly prone to edge damage, twisting and distortion if handled as individual items. Care taken to avoid localized damage where component touch each other, to unstiffened edges at lifting points or other zones where a significant proportion of the weight of the bundle is imposed on a single unreinforced edge
Storage	
4	Stacking of manufactured components stored before transportation or erection clear of the ground to be kept clean
5	Necessary supports to avoid permanent deformations
6	Storage of profiled sheeting, and other materials supplied with pre-finished decorative surfaces according to the requirements of relevant standards
Protection against corrosion	
7	Avoidance of accumulation of water
8	Precautions in order to avoid the penetration of moisture into bundles of sections with metallic pre-coatings NOTE In case of prolonged open storage on site the bundles of sections should be opened and the sections separated to avoid the occurrence of 'black or white rust'.
9	Appropriate corrosion protection treatment of cold formed steel components less than 4 mm thick done before leaving the manufacturing works, sufficient at least to resist the exposure likely to be experienced during transportation, storage and initial erection
Stainless steels	
10	Handling and storage of stainless steel so as to prevent contamination by fixtures or manipulators etc. Careful storage of stainless steel, so that the surfaces are protected from damage or contamination
11	Use of protective film or other coating, to be left on as long as practicable
12	Avoidance of storage in salt-laden humid atmospheres
13	Protection of storage racks by wooden, rubber or plastic battens or sheaths to avoid carbon steel, copper-containing, lead etc. rubbing surfaces
14	Use of markers containing chloride or sulphide prohibited NOTE An alternative is to use protective film and apply all marks only into this film.
15	Protection of stainless steel from direct contact with carbon steel lifting tackle or handling equipment such as chains, hooks, strapping and rollers or the forks of fork lift trucks by use of isolating materials or light plywood or suction cups. Use of appropriate erection tools to ensure that surface contamination does not occur
16	Avoidance of contact with chemicals, including dyes, glues, adhesive tape, undue amounts of oil and grease NOTE If it is necessary to use them, their suitability is to be checked with their manufacturer.
17	Use of segregated manufacturing used for carbon steel and stainless steel to prevent carbon steel pick-up. Use of separate tools dedicated for use with stainless steel only, particularly grinding wheels and wire brushes. Wire brushes and wire wool of stainless steel, preferably an austenitic grade
Transport	
18	Special measures needed for protecting manufactured components in transit

6.4 Cutting

6.4.1 General

Cutting shall be carried out in such a way that the requirements for geometrical tolerances, maximum hardness and smoothness of free edges as specified in this European Standard are met.

NOTE Known and recognised cutting methods are sawing, shearing, disc cutting, water jet techniques and thermal cutting. Hand thermal cutting should be used only if it is not practical to use machine thermal cutting.

If a process does not conform, it shall not be used until corrected and checked again. It may be used on a restricted range of constituent products that do produce conforming results.

If coated materials are to be cut, the method of cutting shall be selected to minimize the damage on the coating.

Burrs that could cause injury or prevent the proper alignment or bedding of sections or sheeting shall be removed.

6.4.2 Shearing and nibbling

The free edge surfaces shall be checked and smoothed as necessary in order to remove significant defects. If grinding or machining is used after shearing or nibbling, the minimum depth of grinding or machining shall be 0,5 mm.

6.4.3 Thermal cutting

The capability of thermal cutting processes shall be periodically checked as set out below.

Four samples shall be produced from the constituent product to be cut by the process:

1) a straight cut from the thickest constituent product;

2) a straight cut from the thinnest constituent product;

3) a sharp corner from a representative thickness;

4) a curved arc from a representative thickness.

Measurements shall be taken on the straight samples over at least a 200 mm length on each and checked against the required quality class. The sharp corner and curved samples shall be inspected to establish that they produce edges of equivalent standard to the straight cuts.

The quality of cut surfaces defined in accordance with EN ISO 9013 shall be as follows:

a) for EXC1 cut edges that are free from significant irregularities are acceptable provided that any dross is removed. For perpendicularity or angularity tolerance, u, range 5 may be used;

b) Table 9 specifies the requirements for other execution classes.

Table 9 — Quality of the cut surfaces

	Perpendicularity or angularity tolerance, u	Mean height of the profile, Rz5
EXC2	Range 4	Range 4
EXC3	Range 4	Range 4
EXC4	Range 3	Range 3

6.4.4 Hardness of free edge surfaces

For carbon steels, if specified, hardness of free edge surfaces shall be in accordance with Table 10. In this case processes that are likely to produce local hardness (thermal cutting, shearing, punching) shall have their capability checked. In order to achieve the required hardness of free edge surfaces, preheating of material shall be applied as necessary.

Table 10 — Permitted maximum hardness values (HV 10)

Product standards	Steel grades	Hardness values
EN 10025-2 to -5	S235 to S460	380
EN 10210-1, EN 10219-1		
EN 10149-2 and EN 10149-3	S260 to S700	450
EN 10025-6	S460 to S690	
NOTE These values are in accordance with EN ISO 15614-1 applied to steel grades listed in ISO/TR 20172.		

Unless otherwise specified, the check of the capability of the processes shall be as follows:

a) four samples shall be produced from procedure tests on constituent product encompassing the range of constituent products processed that are most susceptible to local hardening;

b) four local hardness tests shall be done on each sample in locations likely to be affected. The tests shall be in accordance with EN ISO 6507.

NOTE The requirements for checking of hardness after welding are included in procedure testing (see 7.4.1).

6.5 Shaping

6.5.1 General

Steel may be bent, pressed or forged to the required shape either by the hot or by the cold forming processes, provided the properties are not reduced below those specified for the worked material.

Requirements and recommendations for hot, cold forming and flame straightening of steels shall be as given in the relevant product standards and in CEN/TR 10347.

Shaping by controlled application of heat may be used under the conditions specified in 6.5.2 and 6.5.3.

Shaped components that exhibit cracking or lamellar tearing, or damage to surface coatings, shall be treated as non conforming products.

6.5.2 Hot forming

Shaping by hot forming shall conform to the requirements relating to hot forming of the relevant product standard and to the recommendations of the steel manufacturer.

For steels according to EN 10025-4 hot forming is not permitted.

For quenched and tempered steels hot forming is not permitted unless the requirements of EN 10025-6 are fulfilled.

Shaping by hot forming (T > 580 °C) of cold formed thin gauge components and sheeting is not permitted if the nominal yield strength is achieved by cold forming.

For steel grades up to and including S355, the hot forming process shall take place in the red-hot state and the temperature, timing and cooling rate shall be appropriate to the particular type of steel. Bending and forming in the blue heat range (250 °C to 380 °C) is not permitted.

For steel grades S450+N (or +AR) according to EN 10025-2, and S420 and S460 according to EN 10025-3, the hot forming process shall take place in the temperature range 960 °C to 750 °C with subsequent cooling at air temperature. The cooling rate should be such as to prevent hardening as well as excessive grain coarsening. If this is not practicable, a subsequent normalising treatment shall be carried out.

Hot forming is not allowed for S450 according to EN 10025-2 if no delivery condition is indicated.

NOTE If no delivery condition is indicated, steel products S450 could be delivered in the thermomechanical delivery condition.

6.5.3 Flame straightening

If distortion is to be corrected by flame straightening, this shall be undertaken by local application of heat, ensuring that the maximum steel temperature and the cooling procedure are controlled.

For EXC3 and EXC4 a suitable procedure shall be developed. The procedure shall include at least:

a) maximum steel temperature and procedure of cooling allowed;

b) method of heating;

c) method used for temperature measurements;

d) results of mechanical tests carried out for the process approval;

e) identification of workers entitled to apply the process.

6.5.4 Cold forming

Shaping by cold forming, produced either by roll forming, pressing or folding shall conform to the requirements for cold formability given in the relevant product standard. Hammering shall not be used.

NOTE Cold forming leads to reduction in the ductility. Furthermore attention is drawn to the risk of hydrogen embrittlement associated with subsequent processes such as acid treatment during coating or hot dip galvanization.

a) For steel grades higher than S355, if a stress relief treatment is carried out after cold forming, the following two conditions shall be satisfied:

   1) temperature range: 530 °C to 580 °C;

   2) holding time: 2 min/mm of material thickness, but with a minimum time of 30 min.

Stress relief treatment at more than 580 °C, or for over an hour, may lead to deterioration of the mechanical properties. If it is intended to stress relieve S420 to S700 steels at higher temperatures or for longer times, the required minimum values of the mechanical properties shall be agreed in advance with the product manufacturer.

b) For stainless steels, unless otherwise specified, the minimum inside bend radii to be formed shall be:

1) 2 t for austenitic grades 1.4301, 1.4401, 1.4404, 1.4541 and 1.4571;

2) 2,5 t for austenitic-ferritic grade 1.4462.

where t is the thickness of the material.

c) For other grades of stainless steels, the minimum inside bend radii shall be specified.

Smaller inside bend radii may be permitted if due consideration is given to issues such as steel specification, condition and thickness and the direction of bending in relation to the rolling direction.

In order to counteract the effects of spring-back, stainless steel needs to be over-bent to a slightly higher degree than carbon steel.

NOTE The power requirement for bending stainless steel are higher than for bending geometrically similar carbon steel components, due to work hardening (by about 50% in the case of the austenitic steels or even more in the case of 1.4462 austenitic-ferritic steel).

d) Cold formed sections and sheeting may be shaped by cranking, smooth curving or crimping as appropriate to the materials to be used.

For cold formed components and sheeting used as structural components, shaping by cold forming shall comply with the following two conditions:

1) the surface coatings and the accuracy of profile shall not be impaired;

2) It shall be specified if constituent products require protective membranes to be applied before forming.

NOTE 1 Some coatings and finishes are particularly prone to abrasive damage, both during forming and subsequently during erection. For further information, see EN 508-1 and EN 508-3.

Bending by cold forming of hollow section components may be used provided that hardness and geometry of the as-bent constituent product are checked.

NOTE 2 Bending by cold forming may cause alteration of section properties (e.g. concavity, ovality and wall thinning) and increased hardness.

e) For circular tubes bending by cold forming shall comply with the following three conditions, unless otherwise specified:

1) the ratio of the overall diameter of the tube to the wall thickness shall not exceed 15;

2) the bend radius (at the centreline of the tube) shall not be less than 1,5d or d+100 mm, whichever is the larger, in which d is the overall diameter of the tube;

3) welded joint in the cross-section shall be positioned close to the neutral axis, in order to reduce the bending stresses at the weld.

6.6 Holing

6.6.1 Dimensions of holes

This clause applies to the making of holes for connections with mechanical fasteners and pins.

The definition of the nominal hole diameter combined with the nominal diameter of the bolt to be used in the hole determines whether the hole is "normal" or "oversize". The terms "short" and "long" applied to slotted holes refer to two types of holes used for the structural design of preloaded bolts. These terms may be used also to designate clearances for non-preloaded bolts. Special dimensions should be specified for movement joints.

The nominal clearances for bolts and for pins not intended to act in fitted conditions shall be as specified in Table 11. The nominal clearance is defined as:

— the difference between the nominal hole diameter and the nominal bolt diameter for round holes;

— the difference between respectively the length or the width of the hole and the nominal bolt diameter for slotted holes.

Table 11 — Nominal clearances for bolts and pins (mm)

Nominal bolt or pin diameter d (mm)	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**27 and over**
Normal round holes [a]	1 [b c]		2					3
Oversize round holes	3		4				6	8
Short slotted holes (on the length) [d]	4		6				8	10
Long slotted holes (on the length) [d]	1,5 d							

[a] For applications such as towers and masts the nominal clearance for normal round holes shall be reduced by 0,5 mm unless otherwise specified.

[b] For coated fasteners, 1 mm nominal clearance can be increased by the coating thickness of the fastener.

[c] Bolts with nominal diameter 12 and 14 mm, or countersunk bolts may also be used in 2 mm clearance holes under conditions given in EN 1993-1-8.

[d] For bolts in slotted holes the nominal clearances across the width shall be the same as the clearances on diameter specified for normal round holes.

For fit bolts the nominal hole diameter shall be equal to the shank diameter of the bolt.

NOTE 1 For fit bolts to EN 14399-8 the nominal diameter of the shank is 1 mm larger than nominal diameter of the threaded portion.

For hot rivets the nominal hole diameter shall be specified.

For countersunk bolts or hot rivets, nominal dimensions of the countersinking and tolerances on those shall be such that after installation the bolt or rivet shall be flush with the outer face of the outer ply. The dimensions of the countersinking shall be specified accordingly. If countersinking through more than one ply the plies shall be held firmly together during countersinking.

If countersunk bolts are identified as being for use in tension or preloaded applications, the nominal depth of countersinking shall be at least 2 mm less than the nominal thickness of the outer ply.

NOTE 2 The 2 mm is to allow for adverse tolerances.

For blind rivets used for the fixing of profile sheeting, the diameter of the clearance hole (d_h) shall comply with the following according to the standards for rivets given in 5.6.11:

d_{nom} + 0,1 mm ≤ d_h ≤ d_{nom} + 0,2 mm with d_{nom}= nominal diameter of the rivet

6.6.2 Tolerances on hole diameter for bolts and pins

Unless otherwise specified, hole diameters shall comply with the following:

a) holes for fit bolts and fitted pins: class H11 according to ISO 286-2;

b) other holes: ± 0,5 mm, the hole diameter being taken as the average of entry and exit diameters (see Figure 1).

6.6.3 Execution of holing

Holes for fasteners or pins may be formed by any process (drilling, punching, laser, plasma or other thermal cutting) provided that this leaves a finished hole such that:

a) cutting requirements relating to local hardness and quality of cut surface, according to 6.4 are fulfilled;

b) all matching holes for fasteners or pins register with each other so that fasteners can be inserted freely through the assembled members in a direction at right angles to the faces in contact.

Punching is permitted provided that the nominal thickness of the component is not greater than the nominal diameter of the hole, or for a non-circular hole, its minimum dimension.

For EXC1 and EXC2, holes may be formed by punching without reaming unless otherwise specified.

- For EXC3 and EXC4, punching without reaming is not permitted. The holes shall be punched at least 2 mm undersize in diameter.

- The capability of holing processes shall be checked periodically as follows:

    - eight samples shall be produced from procedure tests on constituent product encompassing the range of hole diameters, constituent product thickness and grades processed;

    - hole sizes shall be checked at both ends of each hole using go/no go gauges. Holes shall comply with the tolerance class as specified in 6.6.2.

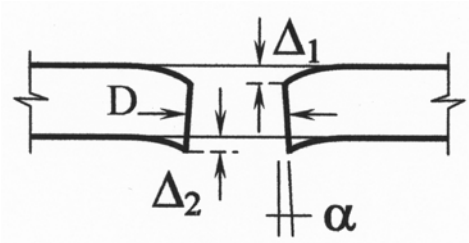
If the process does not conform it shall not be used until corrected. It may be used on a restricted range of constituent products and hole sizes that do produce conforming results.

Holes shall also conform to the following:

1) the taper angle (α) shall not exceed that shown in Figure 1;

2) the burrs (Δ) shall not exceed that shown in Figure 1;

3) at splices, the holes in mating surfaces shall be punched in one direction in all components.



$$D = \frac{(d_{max} + d_{min})}{2}$$

max (Δ_1 or Δ_2) ≤ max (D/10 ; 1 mm)

$\alpha \leq 4°$ (i.e. 7 %);

Figure 1 — Permitted distortions of punched holes and plasma cuts

Holes for fit bolts and fit pins may be either drilled full size or reamed in situ. If the holes are to be reamed in situ, they shall be made at least 3 mm undersized initially by drilling or punching. If the fastener is to fit through multiple plies they shall be held firmly together during drilling or reaming. The reaming shall be carried out with a fixed spindle device. Acidic lubricant shall not be used.

Countersinking of normal round holes for countersunk bolts or rivets shall be undertaken after holing.

Long slotted holes shall be either punched in one operation or formed by drilling or punching two holes and completed by hand thermal cutting, unless otherwise specified.

For cold formed components and sheeting, slotted holes may be formed by punching in a single operation, consecutive punching, or joining two punched or drilled holes by use of a jig saw.

Burrs shall be removed from holes before assembly. If holes are drilled in one operation through parts clamped together which would not otherwise be separated after drilling, removing of burrs is necessary only from the outside holes.

6.7 Cut outs

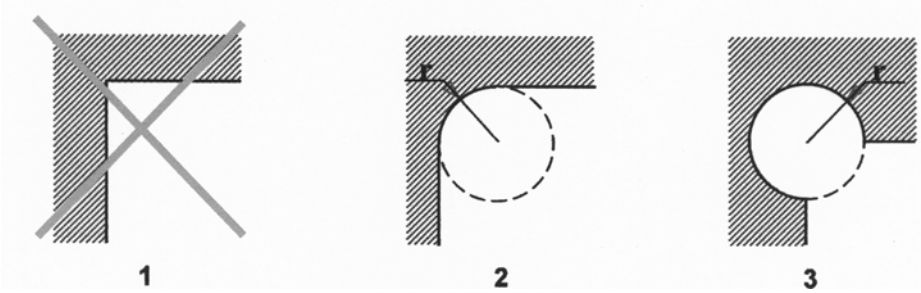
Over-cutting of re-entrant corners shall not be permitted. Re-entrant corners are those where the open angle between the faces is less than 180°.

Re-entrant corners and notches shall be rounded off with a minimum radius of:

— 5 mm for EXC2 and EXC3.

— 10 mm for EXC4.

Examples are given in Figure 2.



Key
1 not permitted
2 Form A (recommended for fully mechanised or automatic cutting)
3 Form B (permitted)

Figure 2 — Example of cut outs

At punched cut outs in plates over 16 mm in thickness, the deformed materials shall be removed by grinding. Punched cut outs are not permitted for EXC4.

For thin gauge components and sheeting, locations where sharp re-entrant corners are not permitted shall be specified with the minimum acceptable radii.

6.8 Full contact bearing surfaces

If full contact bearing surfaces are specified, the cutting length, squareness of ends and flatness of surface shall comply with the tolerances specified in Clause 11.

6.9 Assembly

Assembly of components shall be carried out so as to fulfil the specified tolerances.

Precautions shall be taken so as to prevent galvanic corrosion produced by contact between different metallic materials.

Contamination of stainless steel by contact with structural steel should be avoided.

Drifting to align holes shall be carried out in such a way that the elongation does not exceed the values given in D.2.8 No 6 as follows:

— EXC1 and EXC2: Class 1;

— EXC3 and EXC4: Class 2.

In case those values are exceeded holes shall be corrected by reaming.

Holes for which elongation is not permitted shall be identified and not be used for alignment (e.g. for fit bolts).

NOTE In such cases specific alignment holes may be provided.

All connections for temporary components provided for manufacturing purposes shall meet the requirements of this European Standard and any special requirements including those related to fatigue which shall be specified.

Requirements for camber or presets in components shall be checked after completion of assembly.

6.10 Assembly check

The fit between manufactured components that are inter-connected at multiple connection interfaces shall be checked using dimensional templates, accurate three-dimensional measurements or by trial assembly. Requirements for whether, and to what extent, trial assembly is to be used shall be specified.

Trial assembly means putting together sufficient components of a whole structure to check that they fit. It should be considered to prove fit-up between components if this is not provable by using templates or measurement.

7 Welding

7.1 General

Welding shall be undertaken in accordance with the requirements of the relevant part of EN ISO 3834 or EN ISO 14554 as applicable.

NOTE Guidelines for implementation of EN ISO 3834 on quality requirements for fusion welding of metallic materials is given in CEN ISO/TR 3834-6. [29]

According to the execution class, the following parts of EN ISO 3834 apply:

— EXC1: Part 4 "Elementary quality requirements";

— EXC2: Part 3 "Standard quality requirements";

— EXC3 and EXC4: Part 2 "Comprehensive quality requirements".

Arc welding of ferritic steels and stainless steels should follow the requirements and recommendations of EN 1011-1, EN 1011-2, EN 1011-3 as amended in 7.7.

7.2 Welding plan

7.2.1 Requirements for a welding plan

A welding plan shall be provided as part of the production planning required by the relevant part of EN ISO 3834.

7.2.2 Content of a welding plan

Implementation of the welding plan shall include, as relevant:

a) the welding procedure specifications including welding consumable, any preheating, interpass temperature and post weld heat treatment requirements;

b) measures to be taken to avoid distortion during and after welding;

c) the sequence of welding with any restrictions or acceptable locations for start and stop positions, including intermediate stop and start positions where joint geometry is such that welding cannot be executed continuously;

NOTE Guidance for joints of hollow sections is given in Annex E.

d) requirements for intermediate checking;

e) turning of components in the welding process, in connection with the sequence of welding;

f) details of restraints to be applied;

g) measures to be taken to avoid lamellar tearing;

h) special equipment for welding consumables (low hydrogen, conditioning etc.);

i) weld profile and finish for stainless steels;

j) requirements for acceptance criteria of welds in accordance with 7.6;

k) cross reference to 12.4 of the inspection and test plan;

l) requirements for weld identification;

m) requirements for surface treatment according to Clause 10.

If welding or assembly overlaps or masks previous welds special consideration is needed concerning which welds are to be executed first and the possible need to inspect/test a weld before the second weld is executed or before masking components are assembled.

7.3 Welding processes

Welding may be performed by the following welding processes defined in EN ISO 4063:

111: Manual metal-arc welding (metal-arc welding with covered electrode);

114: Self-shielded tubular cored arc welding;

121: Submerged arc welding with one wire electrode;

122: Submerged arc welding with strip electrode;

123: Submerged arc welding with multiple wire electrodes;

124: Submerged arc welding with metallic powder addition;

125: Submerged arc welding with tubular electrodes;

131: Metal inert gas welding; MIG-welding;

135: Metal active gas welding; MAG-welding;

136: Tubular-cored arc welding with active gas shield;

137 Tubular-cored arc welding with inert gas shield;

141: Tungsten inert gas welding TIG welding;

21: Spot welding;

22: Seam welding;

23: Projection welding;

24: Flash welding;

42: Friction welding;

52: Laser welding;

783: Drawn arc stud welding with ceramic ferrule or shielding gas;

784: Short-cycle drawn arc stud welding.

Resistance welding processes 21, 22 and 23 shall only be used to execute welding of thin gauge steel components. Additional information is given:

— in EN ISO 14373 for process 21(spot welding);

— in EN ISO 16433 for process 22 (seam welding;

— in EN ISO 16432 for process 23 (projection welding).

The diameter of spot and projection welds shall be checked during production by means of peel or chisel testing according to EN ISO 10447.

Other welding processes shall only be used if explicitly specified.

7.4 Qualification of welding procedures and welding personnel

7.4.1 Qualification of welding procedures

7.4.1.1 General

Welding shall be carried out with qualified procedures using a welding procedure specification (WPS) in accordance with the relevant part of EN ISO 15609 or EN ISO 14555 or EN ISO 15620, as relevant. If specified, special deposition conditions for tack welds shall be included in the WPS. For joints in hollow section lattice structures the WPS shall define the start and stop zones and the method to be used in order to cope with locations where the welds change from a fillet weld to butt around a joint.

7.4.1.2 Qualification of welding procedures for processes 111, 114, 12, 13 and 14

a) The qualification of the welding procedure depends on the execution class, the parent metal and the degree of mechanization in accordance with Table 12.

b) If EN ISO 15613 or EN ISO 15614-1 qualification procedures are used, the following conditions apply:

   1) If impact tests are specified, they shall be carried out at the lowest temperature for which the standard of the steel grade requires impact properties.

   2) For steels according to EN 10025-6, one specimen for micro-examination is necessary. Photographs of weld metal, fusion line zone and HAZ shall be recorded. Microcracks are not permitted.

   3) If welding on shop primers, tests shall be carried out on the maximum (nominal + tolerance) accepted layer thickness.

c) If a qualification procedure is to apply to transverse stressed fillet welds on steel grades higher than S275, test shall be completed by a cruciform tensile test performed in accordance with EN ISO 9018. Only specimens with $a \leq 0{,}5\ t$ shall be evaluated. Three cross tensile specimen shall be tested. If the fracture happens in the parent metal, the minimum nominal tensile strength of the parent metal shall be reached. If the fracture happens in the weld metal, the fracture strength of the cross section of the actual weld shall be determined. By processes with deep penetration the actual root penetration shall be considered. The determined average fracture strength shall be $\geq 0{,}8\ R_m$ (with R_m = nominal tensile strength of the used parent metal).

Table 12 — Methods of qualification of welding procedures for the processes 111, 114, 12, 13 and 14

Method of qualification		EXC 2	EXC 3	EXC 4
Welding procedure test	EN ISO 15614-1	X	X	X
Pre-production welding test	EN ISO 15613	X	X	X
Standard welding procedure	EN ISO 15612	X [a]	-	-
Previous welding experience	EN ISO 15611	X [b]	-	-
Tested welding consumables	EN ISO 15610			
X Permitted - Not permitted				
[a] Only for materials ≤ S 355 and only for manual or partly mechanized welding. [b] Only for materials ≤ S 275 and only for manual or partly mechanized welding.				

7.4.1.3 Qualification of welding procedures for other welding processes

The qualification of welding procedures of welding processes not covered in 7.4.1.2 shall be performed according to Table 13.

Table 13 — Qualification of welding procedures for the processes 21, 22, 23, 24, 42, 52, 783 and 784

Welding processes (according to EN ISO 4063)		**Welding procedure specification (WPS)**	**Qualification of the welding procedure**
Reference number	**Nomenclature**		
21	Spot welding	EN ISO 15609-5	EN ISO 15612
22	Seam welding		
23	Projection welding		
24	Flash welding	EN ISO 15609-5	EN ISO 15614-13
42	Friction welding	EN ISO 15620	EN ISO 15620
52	Laser welding	EN ISO 15609-4	EN ISO 15614-11
783	Drawn arc stud welding with ceramic ferrule or shielding gas	EN ISO 14555	EN ISO 14555 [a]
784	Short-cycle drawn arc stud welding		
[a] For EXC2, welding procedure qualification based on previous experience is permitted. For EXC3 and EXC4, welding procedure qualification shall be carried out by welding procedure test or pre-production test.			

7.4.1.4 Validity of a welding procedure qualification

The validity of a welding procedure depends on the requirements of the standard used for the qualification. If specified, welding production tests have to be carried out in accordance with the relevant standard of qualification, e.g. EN ISO 14555.

The following additional tests are required for a welding procedure qualified in accordance with EN ISO 15614-1 which is undertaken by a welding process that has not been used:

a) for a period of between one and three years, a suitable production welding test shall be carried out for steel grades higher than S355. Examination and testing shall include visual inspection, radiographic or ultrasonic inspection (not required for fillet welds), surface crack detection by magnetic particle or penetrant test, macro-examination and hardness test;

b) for a period of more than three years,

   1) a macro specimen taken from a production test shall be inspected for acceptability for steel grades up to and including S355, or

   2) new welding procedure tests shall be carried out for steel grades higher than S355 as relevant.

For resistance welding, the welding parameters may be determined using tests according to EN ISO 10447.

7.4.2 Welders and welding operators

Welders shall be qualified in accordance with EN 287-1 and welding operators in accordance with EN 1418.

Welding hollow section branch connection with angles less than 60° shall be qualified by specific test.

Records of all welder and welding operator qualification tests shall be kept available.

7.4.3 Welding coordination

For EXC2, EXC3 and EXC4, welding coordination shall be maintained during the execution of welding by welding coordination personnel suitably qualified for, and experienced in the welding operations they supervise as specified in EN ISO 14731.

With respect to the welding operations being supervised, welding coordination personnel shall have a technical knowledge according to Tables 14 and 15.

NOTE 1 Steel groups are those defined in ISO/TR 15608. Correspondence to steel grades and reference standards can be found in ISO/TR 20172.

NOTE 2 B, S and C are respectively basic, specific and comprehensive knowledge as specified in EN ISO 14731.

Table 14 — Technical knowledge of the coordination personnel
Structural carbon steels

EXC	Steels (steel group)	Reference standards	Thickness (mm)		
			$t \leq 25$ [a]	$25 < t \leq 50$ [b]	$t > 50$
EXC2	S235 to S355 (1.1, 1.2, 1.4)	EN 10025-2, EN 10025-3, EN 10025-4 EN 10025-5, EN 10149-2, EN 10149-3 EN 10210-1, EN 10219-1	B	S	C [c]
	S420 to S700 (1.3, 2, 3)	EN 10025-3, EN 10025-4, EN 10025-6 EN 10149-2, EN 10149-3 EN 10210-1, EN 10219-1	S	C [d]	C
EXC3	S235 to S355 (1.1, 1.2, 1.4)	EN 10025-2, EN 10025-3, EN 10025-4 EN 10025-5, EN 10149-2, EN 10149-3 EN 10210-1, EN 10219-1	S	C	C
	S420 to S700 (1.3, 2, 3)	EN 10025-3, EN 10025-4, EN 10025-6 EN 10149-2, EN 10149-3 EN 10210-1, EN 10219-1	C	C	C
EXC4	All	All	C	C	C

[a] Column base plates and endplates ≤ 50 mm.
[b] Column base plates and endplates ≤ 75 mm.
[c] For steels up to and including S275, level S is sufficient.
[d] For steels N, NL, M and ML, level S is sufficient.

**Table 15 — Technical knowledge of the coordination personnel
Stainless steels**

EXC	Steels (steel group)	Reference standards	Thickness (mm)		
			$t \leq 25$	$25 < t \leq 50$	$t > 50$
EXC2	Austenitic (8)	EN 10088-2:2005, Table 3 EN 10088-3:2005, Table 4 EN 10296-2:2005, Table 1 EN 10297-2:2005, Table 2	B	S	C
	Austenitic-ferritic (10)	EN 10088-2:2005, Table 4 EN 10088-3:2005, Table 5 EN 10296-2:2005, Table 1 EN 10297-2:2005, Table 3	S	C	C
EXC3	Austenitic (8)	EN 10088-2:2005, Table 3 EN 10088-3:2005, Table 4 EN 10296-2:2005, Table 1 EN 10297-2:2005, Table 2	S	C	C
	Austenitic-ferritic (10)	EN 10088-2:2005, Table 4 EN 10088-3:2005, Table 5 EN 10296-2:2005, Table 1 EN 10297-2:2005, Table 3	C	C	C
EXC4	All	All	C	C	C

7.5 Preparation and execution of welding

7.5.1 Joint preparation

7.5.1.1 General

Joint preparation shall be appropriate for the welding process. If qualification of welding procedures is performed in accordance with EN ISO 15614-1, EN ISO 15612 or EN ISO 15613 joint preparation shall comply with the type of preparation used in the welding procedure test. Tolerances for joints preparations and fit-up shall be given in the WPSs.

NOTE 1 EN ISO 9692-1 and EN ISO 9692-2 give some recommended weld preparation details. For weld preparation details of bridge decks, see EN 1993-2:2006, Annex C.

Joint preparation shall be free from visible cracks. For steel grades higher than S460, cut areas shall be descaled by grinding, and verified to be free from cracks by visual inspection, dye penetrant or magnetic particle testing. Visible cracks shall be removed by grinding and the joint geometry corrected as necessary.

If large notches or other errors in joint geometry are corrected by welding a qualified procedure shall be used, and the area shall be subsequently ground smooth and feathered into the adjacent surface.

All surfaces to be welded shall be dry and free from material that would adversely affect the quality of the welds or impede the process of welding (rust, organic material or galvanizing).

Prefabrication primers (shop primers) may be left on the fusion faces only if they do not adversely affect the welding process. For EXC3 and EXC4, prefabrication primers shall not be left on the fusion faces, unless welding procedure tests in accordance with EN ISO 15614-1 or EN ISO 15613 have been completed using such prefabrication primers.

NOTE 2 EN ISO 17652-2 describes tests for assessing the influence of shop primers on the weldability.

7.5.1.2 Hollow sections

Circular hollow sections being used as branch components in fillet welded joints may be cut in straight segments to prepare them for interconnection at saddle joints provided that the fit-up of the joint geometry suits the requirements of the WPS.

For joints between hollow sections welded from one side, the joint preparations given EN ISO 9692-1 and EN ISO 9692-2 shall be used, as appropriate. Annex E illustrates the application given in EN ISO 9692-1 and EN ISO 9692-2 to branch joints between hollow sections.

For branch connections in hollow section lattice structures, any adjustment for lack of fit by a welded surface deposit shall be covered by a suitable welding procedure.

7.5.2 Storage and handling of welding consumables

The welding consumables shall be stored, handled and used in accordance with the manufacturer's recommendations.

If electrodes and fluxes need to be dried and stored, appropriate temperature levels and times shall be fulfilled in accordance with the manufacturer's recommendations or, if not available, with the requirements of Table 16.

Table 16 — Temperature and time for drying and storage of welding consumables

	Temperature level (T)	Time (t)
Drying [a]	300 °C< T ≤ 400 °C	2 h < t ≤ 4 h
Storage [a]	≥ 150 °C	prior to welding
Storage [b]	≥ 100 °C	during welding
[a] Fixed oven	[b] Portable quiver	

Consumables remaining unused at the end of the welding shift shall be dried again in accordance with the above requirements. For electrodes, drying shall be carried out no more than twice. Remaining consumables shall be discarded.

Welding consumables showing signs of damage or deterioration shall be rejected.

NOTE Examples of damage or deterioration include cracked or flaked coatings on covered electrodes, rusty or dirty electrode wires and electrode wires with flaked or damaged copper coatings.

7.5.3 Weather protection

Both the welder and the working area shall be adequately protected against the effects of wind, rain and snow.

NOTE Gas shielded welding processes are particularly sensitive to wind effects.

Surfaces to be welded shall be maintained dry and free from condensation.

If the temperature of material to be welded is below 5 °C suitable heating might be necessary.

For steel grades higher than S355 suitable heating shall be provided if the temperature of the material is below 5 °C.

7.5.4 Assembly for welding

Components to be welded shall be brought into alignment and held in position by tack welds or external devices and maintained during initial welding. Assembly shall be carried out such that the fit-up of joints and the final dimensions of the components are all within the specified tolerances. Suitable allowances shall be made for distortion and shrinkage.

The components to be welded shall be assembled and held in position such that the joints to be welded are readily accessible and easily visible to the welder.

Assembly of hollow section components to be welded should be in accordance with the guidance given in Annex E, unless otherwise specified.

Additional welds shall not be introduced, and the locations of specified welds shall not be changed without ensuring compliance with the specification. Methods of locally strengthening a welded joint in a hollow section lattice structure should facilitate the testing of the integrity of the as-welded joint. The alternative of thickening the component should also be considered.

NOTE Typical details include saddles, diaphragms, division plates, cover plates, cheek plates and through plates.

7.5.5 Preheating

Preheating shall be carried out in accordance with EN ISO 13916 and EN 1011-2.

Preheat shall be undertaken according to applicable WPS and applied during welding, including tack welding and the welding of temporary attachments.

7.5.6 Temporary attachments

If the assembly or erection procedure requires the use of components temporarily attached by welds, they shall be positioned such that they can easily be removed without damage to the permanent steelwork. All welds for temporary attachments shall be made in accordance with the WPS. Any areas where welding of temporary attachments is not permitted shall be specified.

The use of temporary attachments for EXC3 and EXC4 shall be specified.

If temporary welded attachments have to be removed by cutting or chipping, the surface of the parent metal shall subsequently be carefully ground smooth. Cutting and chipping are not permitted for EXC3 and EXC4, unless otherwise specified.

Adequate inspection shall be carried out to ensure that the constituent product is not cracked on the surface at the temporary weld location.

7.5.7 Tack welds

For EXC2, ECX3 and EXC4, tack welds shall be made using a qualified welding procedure. The minimum length of the tack shall be the lesser of four times the thickness of the thicker part or 50 mm, unless a shorter length can be demonstrated as satisfactory by test.

All tack welds not incorporated into the final welds shall be removed. Tack welds that are to be incorporated into the final weld shall have a suitable shape and be carried out by qualified welders. Tack welds shall be free from deposition faults and shall be cleaned thoroughly before final welding. Cracked tack welds shall be removed.

7.5.8 Fillet welds

7.5.8.1 General

A fillet weld, as deposited, shall not be less than the specified dimensions for throat thickness and/or leg length as appropriate, taking into account the following:

a) the full throat thickness shown as achievable using WPSs for deep or partial penetration welding processes;

b) that if a gap h exceeds the imperfection limit, it may be compensated for by an increase in the throat thickness $a = a_{nom} + 0{,}7h$ where a_{nom} is the specified nominal throat thickness. For "Incorrect fit up" (617) quality levels apply provided that the throat thickness is maintained in accordance with (5213);

c) that for bridge decks particular manufacturing requirements apply, e.g. for the throat thickness of fillet welds, see 7.5.18 and D.2.16.

7.5.8.2 Fillet welds for thin gauge components

Fillet welds terminating at the ends or sides of thin gauge components shall be returned continuously around the corners for a distance of not less than twice the leg length of the weld unless access or configuration renders this impracticable. End returns on fillet welds shall be completed unless otherwise specified.

The minimum length of a run of fillet weld, excluding end returns, shall be at least four times the leg length of the weld.

Intermittent fillet weld shall not be used where capillary action could lead to the formation of rust pockets. End runs of fillet welds shall extend to the end of the part connected.

For lap joints, the minimum lap shall be not less than four times the thickness of the thinner connected part. Single fillet welds shall not be used if the parts are not restrained to prevent opening of the joint.

If the end of a component is connected only by longitudinal fillet welds, the length of each weld shall not be less than the transverse spacing between them.

7.5.9 Butt welds

7.5.9.1 General

The location of butt welds used as splices to accommodate available lengths of constituent products shall be checked for consistency with design.

The ends of butt welds shall be terminated in a manner that ensures sound welds with full throat thickness.

For EXC3 and EXC4, and for EXC2 if specified, run-on/run-off pieces shall be used to ensure full throat thickness at the edge. The weldability of such run-on/run-off pieces shall not be less than that of the parent metal.

After completion of the welds, any run-on/run-off pieces or supplementary material shall be removed and their removal shall comply with 7.5.6.

If a flush surface is required, the excess weld metal shall be removed to satisfy the quality requirements.

7.5.9.2 Single sided welds

Full penetration welds welded from one side may be produced with or without metallic or non metallic backing material.

Unless otherwise specified, permanent steel backing material may be used. The requirements for its use shall be included in the WPS.

If steel backing is used, it shall have a carbon equivalent value (CEV) not exceeding 0,43 %, or be the same material as the most weldable of the parent metal to be joined by the weld.

Backing materials shall be fitted tightly to the parent metal and should generally be continuous for the full length of the joint. For EXC3 and EXC4, permanent backing metal shall be made continuous by means of full penetration butt welds. Tack welds shall be included in the butt welds.

Flush grinding of single-sided butt welds in joints between hollow sections executed without backing is not permitted, unless otherwise specified; if those welds are fully backed they may be ground off flush with the general surface profile of the parent metal.

7.5.9.3 Back gouging

Back gouging shall be carried out to a sufficient depth to ensure full penetration into the previously deposited weld metal.

Back gouging shall produce a contour of a single U-shaped groove with its fusion faces readily accessible for welding.

7.5.10 Welds on steels with improved atmospheric corrosion resistance

Welds on steels with improved atmospheric resistance shall be carried out using appropriate welding consumables (see Table 6). As a further option, C-Mn consumables may be used for the body of a multi-run fillet or butt weld provided the capping runs are made using suitable consumables.

7.5.11 Branch connections

Branch connections in hollow section lattice structures, which use combined welded joints (fillet weld and single-sided butt weld), may be welded without backing.

If the bracing angle at the toe of hollow section branch connection is less than 60°, the toe shall be bevelled to permit a butt weld to be used.

NOTE Recommendations for execution of branch connections are given in Annex E.

7.5.12 Stud welding

Stud welding shall be carried out in accordance with EN ISO 14555.

7.5.13 Slot and plug welds

Holes for slot and plug welds shall be proportioned so that adequate access can be provided for welding. Dimensions shall be specified.

NOTE Suitable dimensions are:

a) width: at least 8 mm more than the thickness of the part containing it;

b) length of elongated hole: the lesser of 70 mm or five times the plate thickness.

Plug welds shall be made only on slot welds after the fillet welding in the slot has been checked as satisfactory. Plug welds performed without previous slot welding are not permitted unless otherwise specified.

7.5.14 Spot welds for thin gauge components

7.5.14.1 Arc spot welds

Weld washers should have a thickness of between 1,2 mm and 2,0 mm with a pre-punched hole of 10 mm minimum diameter.

For stainless steels weld washers are accepted only if specified and according to the service conditions.

NOTE 1 Weld washers can introduce crevices into the joint; the acceptability of these crevices depends on the service conditions.

The minimum visible width, d_w, of a circular arc spot weld, or an elongated arc spot weld shall be specified.

NOTE 2 Guidance on the relationship between the interface dimension and the visible width of a circular arc spot weld or an elongated arc spot weld is given in EN 1993-1-3

7.5.14.2 Resistance spot welds

The diameter of a resistance spot weld should correspond as closely as practicable to the recommended tip diameter of the electrode d_r (in mm), given by $d_r = 5\ t^{1/2}$

where

t is the thickness of the sheet in contact with the electrode tip (in mm).

7.5.15 Other weld types

The requirements for other weld types, e.g. seal welds, shall be specified and shall be subject to the same welding requirements as specified in this European Standard.

7.5.16 Post-weld heat treatment

If heat treatment of welded components is necessary, it shall be demonstrated that the procedures used are appropriate.

NOTE Guidance for quality requirements for heat treatment is given in ISO/TR 17663.

7.5.17 Execution of welding

Precautions shall be taken to avoid stray arcing, and if stray arc do occur the surface of the steel shall be lightly ground and checked. Visual checking should be supplemented by penetrant or magnetic particle testing.

Precautions shall be taken to avoid weld spatter. For EXC3 and EXC4, it shall be removed.

Visible imperfections such as cracks, cavities and other not permitted imperfections shall be removed from each run before deposition of further runs.

All slag shall be removed from the surface of each run before each subsequent run is added and from the surface of the finished weld. Particular attention shall be paid to the junctions between the weld and the parent metal.

Any requirements for grinding and dressing of the surface of completed welds shall be specified.

7.5.18 Welding of bridge decks

Production tests shall be carried out according to 12.4.4 c). Production tests are not required for stiffener-deck plate connection outside the roadway (kerbs) which is without loading by vehicles.

For stiffener-deck plate connections and local welds, e.g. at stiffener-stiffener connections with splice plates the starts and stops shall be removed.

For stiffener-crossbeam connections with stiffeners passing through the crossbeam with or without cope holes at first the stiffeners should be welded to the deck plate and the crossbeams subsequently assembled and welded.

7.6 Acceptance criteria

Welded components shall comply with the requirements specified in Clauses 10 and 11.

The acceptance criteria for weld imperfections shall be as follows, with reference to EN ISO 5817, except "Incorrect toe" (505) and "Micro lack of fusion" (401) which are not to be taken into account. Any additional requirements specified for weld geometry and profile shall be taken into account.

— EXC1 quality level D;

— EXC2 generally quality level C except quality level D for "Undercut" (5011, 5012), "Overlap" (506), "Stray arc" (601) and "End crater pipe" (2025);

— EXC3 quality level B;

— EXC4 quality level B+ which is quality level B with the additional requirements given in Table 17.

Table 17 — Additional requirements for quality level B+

Imperfection designation		Limits for imperfections [a]
undercut (5011, 5012)		not permitted
internal pores (2011 to 2014)	Butt welds	$d \leq 0{,}1\ s$, but max. 2 mm
	Fillet welds	$d \leq 0{,}1\ a$, but max. 2 mm
solid inclusions (300)	Butt welds	$h \leq 0{,}1\ s$, but max. 1 mm $l \leq s$, but max. 10 mm
	Fillet welds	$h \leq 0{,}1\ a$, but max. 1 mm $l \leq a$, but max. 10 mm
linear misalignment (507)		$h < 0{,}05\ t$, but max. 2 mm
root concavity (515)		Not permitted
Supplementary requirements for bridge decks [a] [b]		
Porosity and gas pores (2011, 2012 and 2014)		Only singular small pores acceptable
Clustered (localized) porosity (2013)		Maximum sum of pores: 2 %
Elongated cavity, worm-hole (2015 and 2016)		No long pores
Incorrect root gap for fillet welds (617)		Transverse welds to be tested totally, small root reset only locally acceptable $h \leq 0{,}3$ mm + $0{,}1\ a$, but max. 1 mm
Undercut (5011)		a) butt welds: only locally acceptable $h \leq 0{,}5$ mm b) fillet welds: not acceptable where transverse to stress direction, undercuts have to be removed by grinding
Multiple discontinuities in a cross section (n°4.1)		Not permitted
Solid inclusions (300)		Not permitted

[a] Symbols are defined in EN ISO 5817.

[b] These requirements are supplementary to B+.

In case of nonconformities with the above criteria, each case should be judged individually. Such evaluation should be based on the function of the component and the characteristics of the imperfections (type, size, location) in order to decide whether the weld is either acceptable or shall be repaired.

NOTE EN 1993-1-1, EN 1993-1-9 and EN 1993-2 may be used to evaluate the acceptability of imperfections.

7.7 Welding of stainless steels

7.7.1 Amendments to EN 1011-1 requirements

— Clause 13, Paragraph 1— Addition:

Contact pyrometers shall be used to measure temperature unless other methods are specified. Temperature indicating crayons shall not be used.

— Clause 19 — Addition:

Welding procedure qualification records and associated WPSs that do not include a thermal efficiency factor in a heat input calculation may be used provided the heat input is adjusted in accordance with the appropriate thermal efficiency factor.

7.7.2 Amendments to EN 1011-3 requirements

— 7.1, Paragraph 4 — Modification:

The required surface finish of the weld zones shall be specified. It shall be specified if the coloured oxide films formed during welding shall be removed. Due consideration should be given to corrosion resistance, environment, aesthetics and the implications of dressing off and cleaning the weld zone. All slag associated with welding shall be removed unless otherwise specified.

NOTE The discolouration of the weld zone after welding is influenced by the amount of oxygen in the "backing gas" during welding. Coloured photographic reference scales are available to assist with specifying acceptable discolouration [49].

— 7.1, Paragraph 5 — Modification:

After preparation of joint faces, oxidation, hardening and general contamination from thermal cutting processes may need to be eliminated by mechanically machining to a sufficient depth from the cut face. During shearing cracking may occur; these cracks shall be removed prior to welding.

— 7.3, Paragraph 3 — Addition at the beginning of the paragraph:

Copper backing shall not be used unless otherwise specified.

— Clause 10 — Addition:

Appropriate care shall be taken in the disposal of all post weld cleaning materials.

— A.1.2, Paragraph 1 — Modification to last sentence:

The approximate microstructure, which will form in the weld metal, may be indicated from the balance of ferrite and austenite stabilizing elements using a Schaeffler, DeLong, W.R.C. or Espy diagram. If used, the appropriate diagram shall be specified.

— A.2.2, Paragraph 4 — Modification:

The Schaeffler, DeLong, W.R.C. or Espy diagrams may be used to indicate if the consumable will provide the correct ferrite content, taking dilution effects into account. If used, the appropriate diagram shall be specified.

— A.4.1 — Addition:

Welded connections shall not be subject to heat treatment after welding unless permitted by specification.

— C.4. — Addition:

Welded connections shall not be subject to heat treatment after welding unless permitted by specification.

7.7.3 Welding dissimilar steels

The requirements for welding different stainless steel types to each other or to other steels, such as carbon steels, shall be specified.

The welding coordinator shall take into account the appropriate welding techniques, welding processes and welding consumables. The issues associated with contamination of the stainless steel and galvanic corrosion should be considered carefully.

8 Mechanical fastening

8.1 General

This clause covers requirements for shop and site fastening including the fixing of profiled sheeting.

Separate components forming part of a common ply shall not differ in thickness by more than D, where D is 2 mm generally and 1 mm in preloaded applications, see Figure 3. If steel packing plates are provided to ensure that the difference in thickness does not exceed the above limit, their thickness shall not be less than 2 mm.

In case of severe exposure, avoiding cavity corrosion may require closer contact.

Plate thickness shall be chosen to limit the number of packing plates to a maximum of three.

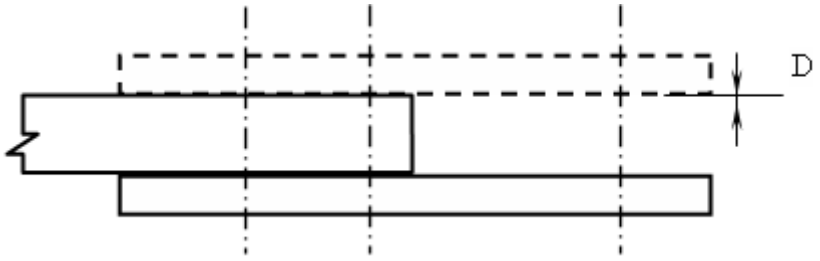


Figure 3 — Difference of thickness between components of a common ply

Packing plates shall have compatible corrosion behaviour and mechanical strength with the adjacent plate components of the connection. Full consideration shall be given to the risk and implication of galvanic corrosion resulting from dissimilar metals being in contact.

8.2 Use of bolting assemblies

8.2.1 General

This clause refers to bolting assemblies specified in 5.6, consisting of matching bolts, nuts and washers (as necessary).

It shall be specified if, in addition to tightening, other measures or means are to be used to secure the nuts.

Bolted connections with small clamp lengths in thin gauge components subject to significant vibrations, such as storage racks, shall use a locking method.

Preloaded assemblies do not need additional locking devices.

Bolts and nuts shall not be welded, unless otherwise specified.

NOTE This does not apply to special weld nuts according to e.g. EN ISO 21670 or weld studs.

8.2.2 Bolts

The nominal fastener diameter used for structural bolting shall be at least M 12, unless otherwise specified together with the associated requirements. For thin gauge components and sheeting the minimum diameter shall be specified for each type of fastener.

The bolt length shall be chosen such that after tightening the following requirements are met for bolt end protrusion beyond the nut face and the thread length.

The length of protrusion shall be at least the length of one thread pitch measured from the outer face of the nut to the end of the bolt.

If it is intended that a connection utilises the shear capacity of the unthreaded shank of bolts, then the dimensions of the bolts shall be specified to allow for the tolerances on the length of the unthreaded portion.

NOTE The length of the unthreaded bolt shaft of full cross section is shorter than the nominal unthreaded length (e.g. by up to 12mm for an M20 bolt).

For non-preloaded bolts, at least one full thread (in addition to the thread run out) shall remain clear between the bearing surface of the nut and the unthreaded part of the shank.

For preloaded bolts according to EN 14399-3 and EN 14399-7, at least four full threads (in addition to the thread run out) shall remain clear between the bearing surface of the nut and the unthreaded part of the shank.

For preloaded bolts according to EN 14399-4 and EN 14399-8, clamp lengths shall be in accordance with those specified in Table A.1 of EN 14399-4:2005.

8.2.3 Nuts

Nuts shall run freely on their partnering bolt, which is easily checked during hand assembly. Any nut and bolt assembly where the nut does not run freely shall be discarded. If a power tool is used, either of the following two checks may be used:

a) for each new batch of nuts or bolts their compatibility may be checked by hand assembly before installation;

b) for mounted bolt assemblies but prior to tightening, sample nuts may be checked for free-running by hand after initial loosening.

Nuts shall be assembled so that their designation markings are visible for inspection after assembly.

8.2.4 Washers

Generally washers are not required for use with non-preloaded bolts in normal round holes. If required, it shall be specified whether washers are to be placed under the nut or the bolt head, whichever is rotated, or both. For single lap connections with only one bolt row, washers are required under both bolt head and the nut.

NOTE The use of washers can reduce local damage to metal coatings particularly where these are thick coatings.

Washers used under heads of preloaded bolts shall be chamfered according to EN 14399-6 and positioned with the chamfer towards the bolt head. Washers according to EN 14399-5 shall only be used under nuts.

Plain washers (or if necessary hardened taper washers) shall be used for preloaded bolts as follows:

a) for 8.8 bolts a washer shall be used under the bolt head or the nut, whichever is to be rotated;

b) for 10.9 bolts washers shall be used under both the bolt head and the nut.

Plate washers shall be used for connections with long slotted and oversized holes. One additional plate washer or up to three washers with a maximum combined thickness of 12 mm may be used in order to adjust the grip length of bolt assemblies. They shall be placed on the side that is not turned.

Dimensions and steel grades of plate washers shall be specified. They shall not be thinner than 4 mm.

Taper washers shall be used if the surface of the constituent product is at an angle to a plane perpendicular to the bolt axis of more than:

a) 1/20 (3°) for bolts with $d \leq 20$ mm;

b) 1/30 (2°) for bolts with $d > 20$ mm.

Dimensions and steel grades of taper washers shall be specified.

8.3 Tightening of non-preloaded bolts

The connected components shall be drawn together such that they achieve firm contact. Shims may be used to adjust the fit. For constituent products with $t \geq 4$ mm for plates and sheeting and $t \geq 8$ mm for sections, unless full contact bearing is specified, residual gaps of up to 4 mm may be left at the edges on condition that contact bearing is achieved at the central part of a connection.

Each bolt assembly shall be brought at least to a snug-tight condition, with special care being given to avoid over-tightening especially short bolts and M12. The tightening process shall be carried out from bolt to bolt of the group, starting from the most rigid part of the connection and moving progressively towards the least rigid part. To achieve a uniform snug-tight condition, more than one cycle of tightening may be necessary.

NOTE 1 The most rigid part of a cover plate connection of an I section is commonly in the middle of the connection bolt group. The most rigid parts of end plate connections of I sections are usually beside the flanges.

NOTE 2 The term "snug-tight" can generally be taken as that achievable by the effort of one man using a normal sized spanner without an extension arm, and can be set as the point at which a percussion wrench starts hammering.

The bolt shall protrude from the face of the nut after tightening not less than one full thread pitch.

8.4 Preparation of contact surfaces in slip resistant connections

This clause is not applicable to stainless steels for which any requirement related to contact surfaces shall be specified.

This clause does not deal with corrosion protection for which requirements are specified in Clause 10 and Annex F.

The area of contact surfaces in preloaded connections shall be specified.

The contact surfaces shall be prepared to produce the required slip factor which shall generally be determined by test as specified in Annex G.

The following precautions shall be taken prior to assembly:

a) the contact surfaces shall be free from all contaminants, such as oil, dirt or paint. Burrs that would prevent solid seating of the connecting parts shall be removed;

b) uncoated surfaces shall be freed from all films of rust and other loose material. Care shall be taken not to damage or smooth the roughened surface. Untreated areas around the perimeter of the tightened connection shall be left untreated until any inspection of the connection has been completed.

Surface treatment that may be assumed to provide the minimum slip factor according to the specified class of friction surface without test are given in Table 18.

Table 18 — Classifications that may be assumed for friction surfaces

Surface treatment	Class	Slip factor μ
Surfaces blasted with shot or grit with loose rust removed, not pitted.	A	0,50
Surfaces blasted with shot or grit: a) spray-metallized with a aluminium or zinc based product; b) with alkali-zinc silicate paint with a thickness of 50 μm to 80 μm	B	0,40
Surfaces cleaned by wire-brushing or flame cleaning, with loose rust removed	C	0,30
Surfaces as rolled	D	0,20

These requirements apply also to packing plates provided to offset differences in thickness as specified in 8.1.

8.5 Tightening of preloaded bolts

8.5.1 General

Unless otherwise specified the nominal minimum preloading force $F_{p,C}$ shall be taken as:

$F_{p,C} = 0,7\ f_{ub}A_s$ where f_{ub} is the nominal ultimate strength of the bolt material and A_s is the stress area of the bolt

as defined in EN 1993-1-8 and specified in Table 19. This level of preload shall be used for all slip resistant preloaded connections and for all other preloaded connections unless a lower level of preload is specified. In the latter case, the bolt assemblies, the tightening method, the tightening parameters and the inspection requirements shall also be specified.

NOTE Preload may be used for slip resistance, for seismic connections, for fatigue resistance, for execution purposes, or as a quality measure (e.g. for durability).

Table 19 — Values of $F_{p,C}$ in [kN]

Property class	Bolt diameter in mm							
	12	16	20	22	24	27	30	36
8.8	47	88	137	170	198	257	314	458
10.9	59	110	172	212	247	321	393	572

Any of the tightening methods given in Table 20 may be used unless restricitions on their use are specified. The *k*-class (as-delivered calibration condition) of the bolting assembly shall be in accordance with Table 20 for the method used.

Table 20 — k-classes for tightening methods

Tightening method	k-classes
Torque method	K2
Combined method	K2 or K1
HRC tightening method	K0 with HRD nut only or K2
Direct tension indicator (DTI) method	K2, K1 or K0

As an alternative, calibration to Annex H may be used, except for the torque method unless this is permitted in the execution specification.

The as-delivered calibration is valid for tightening by rotation of the nut. If tightening is done by rotation of the bolt head, calibration shall be done according to Annex H or by supplementary testing from the fastener manufacturer otherwise in accordance with EN 14399-2.

Burrs, loose material and excessive thickness of paint that would prevent solid seating of the connecting parts shall be removed before assembly.

Before commencement of preloading, the connected components shall be fitted together and the bolts in a bolt group shall be tightened in accordance with 8.3 but the residual gap shall be limited to 2 mm with the necessary corrective action on steel components.

Tightening shall be performed by rotation of the nut except where the access to the nut side of the assembly is inadequate. Special precautions, depending on the tightening method adopted, may have to be taken when bolts are tightened by rotation of the bolt head.

Tightening shall be carried out progressively from the most rigid part of the joint to the least rigid part. To achieve uniform preloading, more than one cycle of tightening may be necessary.

Torque wrenches used in all steps of the torque method shall be capable of an accuracy of ± 4 % according to EN ISO 6789. Each wrench shall be checked for accuracy at least weekly, and in case of pneumatic wrenches, every time the hose length is changed. For torque wrenches used in the first step of the combined method these requirements are modified to ± 10 % for the accuracy and yearly for the periodicity.

Checking shall be carried out after any incident occurring during use (significant impact, fall, overloading etc.) and affecting the wrench.

Other tightening methods (e.g. axial preloading by hydraulic devices or tensioning with ultrasonic control) shall be calibrated in accordance with the recommendations from the equipment manufacturer.

High strength bolts for preloading shall be used without alteration to the as-delivered lubrication unless DTI method or the procedure in Annex H is adopted.

If a bolt assembly has been tightened to the minimum preload and is later un-tightened, it shall be removed and the whole assembly shall be discarded.

Bolt assemblies used for achieving initial fit up should not generally need to be tightened to the minimum preload or un-tightened, and would therefore still be usable in location in the final bolting up process.

NOTE If the tightening process is delayed under uncontrolled exposure conditions the performance of the lubrication may be altered and should be checked.

The potential loss of preloading force from its initial value due to several factors, e.g. relaxation, creep of surface coatings (see Annex F.4 and Table 18), is considered in the tightening methods specified below. In case of thick surface coatings, it shall be specified if measures shall be taken to offset possible subsequent loss of preloading force.

NOTE If the torque method is used this may be by retightening after a delay of some days.

8.5.2 Torque reference values

The torque reference values $M_{r,i}$ to be used for a nominal minimum preloading force Fp,C are determined for each type of bolt and nut combination used by one of the following options:

a) values based on *k*-class declared by the fastener manufacturer in accordance with the relevant parts of EN 14399:

   1) $M_{r,2} = k_m\, d\, F_{p,C}$ with k_m for *k*-class K2.

   2) $M_{r,1} = k_m\, d\, F_{p,C}$ with k_m for *k*-class K1.

b) values determined according to Annex H:

   1) $M_{r,test} = M_m$ with M_m determined according to the procedure relevant to the tightening method to be used.

8.5.3 Torque method

The bolts shall be tightened using a torque wrench offering a suitable operating range. Hand or power operated wrenches may be used. Impact wrenches may be used for the first step of tightening for each bolt.

The tightening torque shall be applied continuously and smoothly.

Tightening by the torque method comprises at least the two following steps:

a) a first tightening step: the wrench shall be set to a torque value of about 0,75 $M_{r,i}$ with $M_{r,i} = M_{r,2}$ or $M_{r,test}$. This first step shall be completed for all bolts in one connection prior to commencement of the second step;

b) a second tightening step: the wrench shall be set to a torque value of 1,10 $M_{r,i}$ with $M_{r,i} = M_{r,2}$ or $M_{r,test}$.

NOTE The use of the 1,10 coefficient with $M_{r,2}$ is equivalent to (1 + 1,65 Vk) with Vk=0,06 for kclass K2.

8.5.4 Combined method

Tightening by the combined method comprises two steps:

a) a first tightening step, using a torque wrench offering a suitable operating range. The wrench shall be set to a torque value of about 0,75 $M_{r,i}$ with $M_{r,i} = M_{r,2}$ or $M_{r,1}$ or $M_{r,test}$. This first step shall be completed for all bolts in one connection prior to commencement of the second step;

When using $M_{r,1}$, for simplification $M_{r,1}$ = 0,13 d Fp,C may be used unless otherwise specified

b) a second tightening step in which a specified part turn is applied to the turned part of the assembly. The position of the nut relative to the bolt threads shall be marked after the first step, using a marking crayon or marking paint, so that the final rotation of the nut relative to the thread in this second step can be easily determined.

The second step shall be in accordance with the values given Table 21 unless otherwise specified.

Table 21 — Combined method: additional rotation (8.8 and 10.9 bolts)

Total nominal thickness "*t*" of parts to be connected (including all packs and washers) *d* = bolt diameter	Further rotation to be applied, during the second step of tightening	
	Degrees	Part turn
$t < 2\,d$	60	1/6
$2\,d \leq t < 6\,d$	90	1/4
$6\,d \leq t \leq 10\,d$	120	1/3
NOTE Where the surface under the bolt head or nut (allowing for taper washers, if used) is not perpendicular to the bolt axis, the required angle of rotation should be determined by testing		

8.5.5 HRC method

The HRC bolts shall be tightened using a specific shear wrench equipped with two co-axial sockets which react by torque one against the other. The outer socket which engages the nut rotates clockwise. The inner socket which engages the spline end of the bolt rotates anticlockwise.

NOTE 1 The shear wrench operates as follows:

- during the tightening operation of an assembly, the socket in rotation is the one that finds the least resistance to it;

- from the outset and right up to the last tightening stage, the outer socket on the nut rotates clockwise while the inner socket holds the spline end without rotating, the result being that the bolt assembly is progressively tightened by the increasing torque applied to the nut;

- at the last tightening stage, i.e. when the torsional resistance plateau of the break-neck section is attained, the inner socket rotates anticlockwise while the outer socket on nut provides the reaction without rotating;

- the bolt assembly installation is complete when the spline end shears off at the break-neck section.

The specified preload requirement is controlled by the HRC bolt itself by means of the geometrical and torsion mechanical characteristics together with the lubrication conditions. The equipment does not need calibration.

In order to ensure that the preloads in fully installed bolts in connections meet the specified minimum preload requirement, the bolt installation process generally comprises two tightening steps; both using the shear wrench.

The first tightening step is achieved at the latest when the shear wrench outer socket stops turning. If specified this first step is repeated as often as required. This first step shall be completed for all bolts in one connection prior to commencement of the second step.

NOTE 2 Guidance of the equipment manufacturer may give additional information on how to identify if pretightening has occurred, e.g. sound of shear wrench changing, or if other methods of pretightening are suitable.

The second tightening step is achieved when the spline end of the bolt shears off at the break-neck.

If the assembly conditions are such that it is not possible to use the shear wrench on the HRC bolt assembly, e.g. for lack of space, tightening shall be carried out using the torque control method, see 8.5.3, with the aid of the k-class K2 information or using a direct tension indicator, see 8.5.6.

8.5.6 Direct tension indicator method

This subclause applies to compressible washers, such as direct tension indicators in accordance with prEN 14399-9, which indicate at least the required minimum preload has been achieved, by monitoring the

force in the bolt. It does not cover indicators that rely on torsion. It does not apply to direct measurement of bolt preload by use of hydraulic instruments.

The direct tension indicators and their associated washers shall be assembled as specified in Annex J.

The first step of tightening to reach a uniform "snug-tight" condition of a fastener assembly shall be when initial deformation of the DTI protrusions begins. This first step shall be completed for all bolts in one connection prior to commencement of the second step.

The second step of tightening shall be as prEN 14399-9 and Annex J. The gaps measured on the indicating washer may be averaged to establish the acceptability of the bolt assembly.

8.6 Fit bolts

Fit bolts may be used in preloaded or non-preloaded applications, and 8.1 to 8.5 apply as appropriate in addition to the requirements below.

The length of the threaded portion of the shank of the fit bolt (including thread run out) included in the bearing length should not exceed 1/3 of the thickness of the plate unless otherwise specified, see Figure 4.

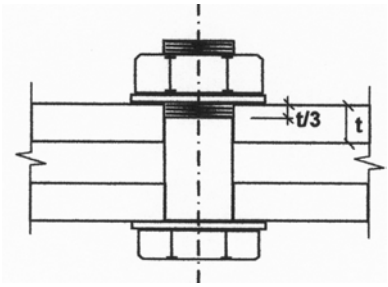


Figure 4 — Threaded portion of the shank in the bearing length for fit bolts

Fit bolts shall be installed without applying excessive force, and in such a way that its thread is not damaged.

8.7 Hot riveting

8.7.1 Rivets

Every rivet shall be of sufficient length to provide a head of uniform dimensions, a complete filling of the hole and to avoid surface indentation by the riveting machine on the outer faces of the plies.

8.7.2 Installation of rivets

The connected components shall be drawn together such that they achieve firm contact and held together during riveting.

Maximum eccentricity between common holes for a rivet in an assembly shall be no more than 1 mm. To meet this requirement reaming is permitted. Following reaming it may be necessary to install a larger diameter of rivet.

For multiple riveted connections, a temporary bolt shall be tightened in at least every fourth hole prior to driving which shall start at the middle of the rivet group. Special measures shall be taken to hold components of single riveted connections together (e.g. clamping).

If practicable, riveting shall be carried out using machines of the steady pressure type. After the upsetting is complete, the driving pressure shall be maintained on the rivets for a short time sufficient for the head to be black when the machine is disengaged.

Every rivet shall be heated uniformly throughout its length, without burning or excessive scaling. It shall be at a consistent bright red heat from the head to point when inserted and shall be upset in its entire length when hot, so as to fill the hole completely. Special care shall be taken in heating and driving long rivets.

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

A burned rivet shall not be used. A heated rivet not used immediately shall not be re-heated for use.

If a flush surface of countersunk rivets is specified protruding rivet metal shall be chipped or ground off.

8.7.3 Acceptance criteria

The rivet heads shall be centred. The head eccentricity relative to the shank axis shall not exceed 0,15 d_0 where d_0 is the hole diameter.

The rivet heads shall be well formed and shall not show cracks or pits.

The rivets shall be in satisfactory contact with the assembled parts both at the outer surface of the plies and in the hole. No movement or vibration shall be detected when the rivet head is lightly tapped with a hammer.

A small well-formed and centred lip may be accepted if only a small number of rivets in the group are concerned.

Outer faces of plies free of indentation by the riveting machine may be specified.

If countersunk rivets are required the heads shall fill the countersink completely after riveting. If the countersinking is not completely filled, the rivet shall be replaced.

Any rivet not meeting the acceptance criteria shall be removed and replaced by a new one.

8.8 Fastening of thin gauge components

8.8.1 General

This clause applies to thin gauge components up to 4 mm thickness.

The performance of fasteners will depend on the site methodology that may be determined by procedure testing. Procedure tests may be used to demonstrate that the required connections can be performed under site conditions. The following aspects should be considered:

a) ability to produce correct hole size for self-tapping screws and rivets;

b) ability to correctly adjust power screwdrivers with the correct tightening torque/depth location;

c) ability to drive a self-drilling screw perpendicular to the connected surface and set sealing washers to correct compression within the limits recommended by the washer manufacturer;

d) ability to select and use cartridge fired pins;

e) ability to form an adequate structural connection and to recognize an inadequate one.

Fasteners shall be used in accordance with the product manufacturer's recommendations.

Use of special fasteners and fastening methods is dealt with in 8.9.

8.8.2 Use of self-tapping and self-drilling screws

The length and thread form of screws shall be selected to suit the specific application and the thickness of the constituent product to be fastened. The effective thread length shall be such that the threaded portion engages in the supporting component.

Screws for certain applications require an interrupted thread. If a sealing washer is used the thickness of the washer should be taken into account in selecting the thread length.

The fasteners shall be located in the valley of the corrugation unless otherwise specified.

If screws are fastened in the crown of a roofing profile care shall be taken to avoid dents in the sheet at the penetration point.

Power tools for fixing screws shall possess an adjustable depth and/or torque control that shall be set in accordance with the equipment manufacturer's recommendations. If power screwdrivers are used, the drilling and driving speeds (revolutions per minute) shall be in accordance with the fastener manufacturer's recommendations.

If sealing washers are used, the screws shall be set to achieve the correct compression as indicated by Figure 5.

The depth gauge, of a power screwdriver, shall be adjusted to compress the elastomeric washer within the limits set by the product manufacturer.

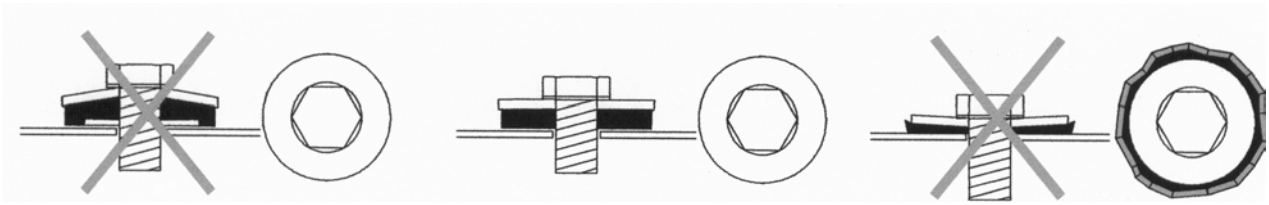


Figure 5 — Guide for compression of sealing washers

Screws without sealing washers shall be set using an appropriate torque or depth control device to avoid overtightening.

The torque control shall be set such that the threading torque is achieved without exceeding either the head-shearing torque or the thread stripping torque.

8.8.3 Use of blind rivets

The choice of the length of the blind rivet shall be according to the total thickness to be fastened.

NOTE 1 The rivet length recommended by the product manufacturer generally takes account of a certain drawing together of the plates to be fastened.

NOTE 2 Most manufacturers offer a range of manually and power operated setting tools to suit high or low volume usage. These are often readily adaptable by changing only the nosepiece and/or setting jaws to set a range of blind rivet types and sizes. Generally interchangeable heads are available for setting where tool access is limited such as inside channels or cylindrical sections.

NOTE 3 Predetermined setting characteristics designed into the rivet body/mandrel relationship ensure consistent joints.

Installation shall be performed according to the product manufacturer's recommendations.

After installation work the ejected broken mandrel stems shall be collected and removed from exterior work surfaces to prevent subsequent corrosion.

8.8.4 Fastening sidelaps

Connections securing panels to each other (sidelaps) and such items as flashing and accessories shall be adequate to draw together overlapping sheets.

Sidelaps of profiled sheets of the exposed surface of a roof should be fastened according to the product manufacturer's recommendations. The minimum diameter of these fasteners should be 4,8 mm for self-tapping and self-drilling screws and 4,0 mm for blind rivets.

If the sheeting is intended to act as a stressed skin, the requirements for the side lap fasteners as structural fasteners shall be specified.

8.9 Use of special fasteners and fastening methods

Special fasteners shall be used and special fastening methods shall be performed in accordance with the product manufacturer's recommendations, and the appropriate sections of 8.1 to 8.8. This also applies to bolts connecting steelwork to other construction materials including chemically anchored foundation bolts.

NOTE 1 Examples of special fastening methods are specially tapped holes, threaded studs, adhesive bonding or clinching using plates that are joined by local deformations.

Such methods shall be used only where specified. Any procedure tests required for use of special fasteners and fastening methods in non-preloaded or preloaded applications shall be specified. Different tests from those specified for bolts may be necessary. Procedure testing may be avoided if sufficient information on previous testing is provided.

Specially tapped holes or threaded studs may be used as equivalent to the use of a bolting assembly in 5.6.3 provided that the materials, thread forms and thread tolerance comply with the respective product standard.

Requirements for use of hexagon injection bolts shall be specified.

NOTE 2 Annex K provides information on the supply and use of hexagon injection bolts that may be invoked.

8.10 Galling and seizure of stainless steels

Galling may result from local adhesion and rupture of surfaces under load and in relative motion during fastening. In some cases, weld bonding and seizure may result.

The following methods may be used to avoid galling problems:

a) dissimilar standard grades of stainless steel may be used which vary in composition, work hardening rate and hardness (e.g. Grade A2-C4, A4-C4 or A2-A4 bolt-nut combination from EN ISO 3506-1 and EN ISO 3506-2);

b) in severe cases, a proprietary high work-hardening stainless steel alloy may be used for one component or hard surface coatings applied, e.g. nitriding or hard chromium plating;

c) anti-galling agents such as PTFE dry film spray.

If dissimilar metals or coatings are used, it is necessary to ensure that the required corrosion resistance is obtained.

NOTE The greasing of bolts is beneficial but may result in contamination by dirt and can present problems for storage.

9 Erection

9.1 General

This clause gives requirements for erection and other work undertaken on site including grouting of bases as well as those relevant to the suitability of the site for safe erection and for accurately prepared supports.

Work carried out on site which includes preparation, welding, mechanical fastening and surface treatment shall comply with the Clauses 6, 7, 8 and 10 respectively.

Inspection and acceptance of the structure shall be performed in accordance with the requirements specified in Clause 12.

9.2 Site conditions

Erection shall not commence until the site for the construction works complies with the technical requirements with respect to the safety of the works, which shall consider such of the following items as are relevant:

a) provision and maintenance of hard standing for cranes and access equipment;

b) access routes to the site and within the site;

c) soil conditions affecting the safe operation of plant;

d) possible settlement of erection supports for the structure;

e) details of underground services, overhead cables or site obstructions;

f) limitations on dimensions or weights of components that can be delivered onto the site;

g) special environmental and climatic conditions on and around the site;

h) particulars of adjacent structures affecting or affected by the works.

Access routes to the site and within the site should be given on a site plan showing dimensions and level of access routes, level of the prepared working area for site traffic and plant, and areas available for storage.

If the works are inter-linked with other trades, technical requirements with respect to the safety of the works shall be checked for consistency with those for other parts of the construction works. This check shall consider such of the following items as are relevant:

i) prearranged procedures for co-operation with other contractors;

j) availability of site services;

k) maximum construction and storage loads permitted on the steelwork;

l) control of concrete placement during composite construction.

NOTE EN 1991-1-6 provides rules for determining construction and storage loads including concrete.

9.3 Erection method

9.3.1 Design basis for the erection method

If the structural stability in the part-erected condition is not evident, a safe method of erection on which the design was based shall be provided. This design basis method of erection shall consider the following items:

a) positions and types of site connections;

b) maximum piece size, weight and location;

c) sequence of erection;

d) stability concept for the part-erected structure including any requirements for temporary bracing or propping;

e) propping or other measures for the execution of phased concreting of composite structures;

f) conditions for removal of temporary bracing or propping, or any requirement for distressing or stressing the structure;

g) features which would create a safety hazard during construction;

h) timing and method for adjustment of foundation connections or bearings and for grouting;

i) camber and presets required in relation of those provided at manufacturing stage;

j) use of profiled steel sheeting to ensure stability;

k) use of profiled steel sheeting to provide lateral restraint;

l) transportation of units, including attachments for lifting, turning or pulling;

m) positions and conditions for supporting and jacking;

n) stability concept for the bearings;

o) deformations of the partly erected structure;

p) expected settlements of the supports;

q) particular positions and loads from cranes, stored components, counter weight etc. for the various construction phases;

r) instructions for the delivery, storage, lifting, building in and pre-tensioning of stayed cables;

s) details of all temporary works and attachments to permanent works with instructions as to their removal.

9.3.2 Constructor's erection method

A method statement describing the constructor's erection method shall be prepared and it shall be checked in accordance with design rules, notably against resistance of the partly erected structure to erection loads and other loading.

The erection method statement may deviate from the design basis method of erection, provided that it is a safe alternative.

Amendments to the erection method statement, including those necessitated by site conditions, shall be checked and reviewed in accordance with the above requirement.

The erection method statement shall describe procedures to be used to safely erect the steelwork and shall take into account the technical requirements regarding the safety of the works.

The procedures should link to specific work instructions.

The erection method statement shall address all relevant items in 9.3.1, and shall consider in addition such of the following items as are relevant:

a) experience from any trial erection undertaken in accordance with 9.6.4;

b) restraints necessary to ensure stability prior to welding and to control local movement of the joint;

c) lifting devices necessary;

d) necessity to mark weights and/or centres of gravity on large or irregularly shaped pieces;

e) relationship between the weights to be lifted and the radius of operation where cranes are to be used;

f) identification of sway or overturning forces, particularly those due to the predicted wind conditions on site during erection, and the exact methods of maintaining adequate sway and overturning resistance;

g) methods of coping with safety hazards;

h) provision of safe working positions and safe means of access to them.

In addition, the following apply for composite steel and concrete structures:

i) sequence of fixing of profiled steel sheeting for composite slabs shall be planned to ensure that sheets are adequately supported by supporting beams before fixing, and are securely fixed before they are used to gain access to subsequent working positions;

j) profiled steel sheets should not be used to gain access for welding of shear connectors unless the sheets are secured already by fasteners that comply with i);

k) sequence of placing and method of securing and sealing permanent formwork to ensure that formwork is secure before being used to gain access for subsequent construction operations and supporting slab reinforcement and deck concrete.

Factors associated with the execution of the concrete works should be considered as relevant, such as sequence of placing concrete, pre-stressing, and temperature difference between steel and freshly placed concrete, jacking and supports.

9.4 Survey

9.4.1 Reference system

Site measurements for the works shall be related to the system established for the setting out and measurement of the construction works in accordance with ISO 4463-1.

A documented survey of a secondary net shall be provided and used as the reference system for setting out the steelwork and establishing the deviations of supports. The coordinates of the secondary net given in this survey shall be accepted as true provided that they comply with the acceptance criteria specified in ISO 4463-1.

The reference temperature for setting out and measuring the steelwork shall be specified.

9.4.2 Position points

The position points which mark the intended position for the erection of individual components shall be in accordance with ISO 4463-1.

9.5 Supports, anchors and bearings

9.5.1 Inspection of supports

The condition and location of the supports shall be checked using appropriate visual and measurement means before the commencement of erection.

If supports are unsuited to erection, they shall be corrected prior to the commencement of erection. Nonconformities shall be documented.

9.5.2 Setting out and suitability of supports

All foundations, foundation bolts and other supports for the steelwork shall be suitably prepared to receive the steel structure. Installation of structural bearings shall comply with the requirements of EN 1337-11.

Erection shall not commence until the location and levels of the supports, anchors or bearings comply with the acceptance criteria in 11.2, or an appropriate amendment to the specified requirements has been issued.

The compliance survey used to check the positions of the supports shall be documented.

If foundation bolts are to be pre-stressed, arrangement shall be made that the upper 100 mm, as a minimum, of the bolt has no adhesion to the concrete.

Foundation bolts intended to move in sleeves should be provided with sleeves three times the diameter of the bolt with a minimum of 75 mm.

9.5.3 Maintaining suitability of supports

Whilst erection is proceeding, the supports for the steelwork shall be maintained in an equivalent condition to their condition at the commencement of erection.

NOTE 1 Areas of supports that require protection against rust staining should be identified and appropriate protection provided.

Compensation for settlement of supports is acceptable, unless otherwise specified. This shall be done by grouting or packing between steelwork and support.

NOTE 2 The compensation will generally be placed beneath the bearing.

9.5.4 Temporary supports

Shims and other supporting devices used as temporary supports under base plates shall present a flat surface to the steel and be of adequate size, strength and rigidity to avoid local crushing of the substructure concrete or masonery.

If packings are subsequently to be grouted, they shall be placed so that the grout totally encloses them with a minimum cover of 25 mm unless otherwise specified.

For bridges, packings shall not be left in position, unless otherwise specified.

If packings are left in position after grouting they shall be made from materials with the same durability as the structure.

If adjustment to the position of the base is achieved using levelling nuts on the foundation bolts under the base plate these may be left in position unless otherwise specified. The nuts shall be selected to ensure that they are suitable to maintain the stability of the part-erected structure but not to jeopardise the performance of the foundation bolt in service.

NOTE As well as shims and blocks, half-nuts or plastic nuts are often used as levelling nuts.

9.5.5 Grouting and sealing

If spaces under base plates are to be grouted, fresh material shall be used in accordance with 5.8.

Grouting material shall be used as follows:

a) the material shall be mixed and used in accordance with product manufacturer's recommendations notably regarding its consistency when used. Material shall not be mixed or used below 0 °C unless the manufacturer's recommendations permit it;

b) the material shall be poured under a suitable head so that the space is completely filled;

c) tamping and ramming against properly fixed supports shall be used if specified and/or recommended by the grout manufacturer;

d) vent holes shall be provided as necessary.

Immediately before grouting, the space under the steel base plate shall be free from liquids, ice, debris and contaminants.

Pocket bases containing columns shall be filled with dense concrete having a characteristic compressive strength not less than that of the surrounding concrete.

In pocket bases, the embedded length of the column shall be initially surrounded with concrete to a sufficient length to provide stability in the temporary state and then remain undisturbed for a period sufficient to gain at least half of its characteristic compressive strength, before removal of any temporary props and wedges.

If treatment of steelwork, bearings and concrete surfaces is required before grouting, it shall be specified.

Care shall be taken that the external profile of grouting allows water to be drained away from structural steel components.

If there is a danger of water or corrosive liquid becoming entrapped during service, the grout around base plates shall not be surcharged such that it rises above the lowest surface of the base plate and the geometry of the concrete grout shall form an angle from the base plate according to Figure 6.

If no grouting is needed, and the edges of the base plate are to be sealed, the method shall be specified.

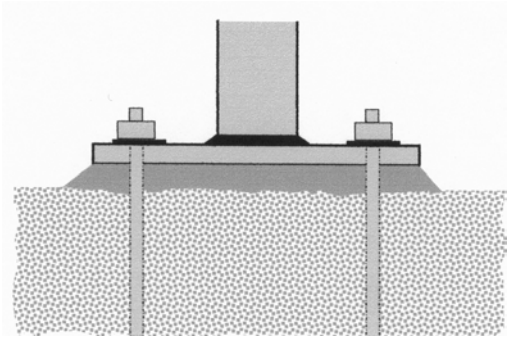


Figure 6 — Grouting under base plate

The concrete and the grouting shall be carried out according to 5.8 and prEN 13670.

9.5.6 Anchoring

Anchoring devices in concrete parts of the structure or adjacent structures shall be set in accordance with their specification.

Suitable measures shall be taken to avoid damage to concrete in order to achieve the necessary anchoring resistance.

NOTE This applies notably to expansion anchors, for which a minimum distance from the facing is necessary in order to avoid concrete bursting.

9.6 Erection and work at site

9.6.1 Erection drawings

Erection drawings or equivalent instructions shall be provided and form a part of the erection method statement.

Drawings shall be prepared showing plans and elevations and at such a scale that the erection marks for all components can be shown on them.

Drawings shall show grid locations, bearing positions and assembly of components together with requirements for tolerances.

Foundation plans shall show the base location and orientation of the steelwork, any other components in direct contact with the foundations, their base location and level, the intended bearing level and the datum level. Foundations shall include column base support and other structural supports.

Elevations shall show required levels for floors and/or structure.

Drawings shall show necessary details for fixing of steel or bolts to the foundations, the method of adjustment by packing and wedging and grout requirements as well as fixing of steelwork and bearings to their supports.

Drawings shall show details and arrangements of any steelwork or other temporary works necessary for erection purposes to ensure the stability of the construction or the safety of personnel.

Drawings shall state the weight of all components or assemblies over 5 tonnes and the centre of gravity of all large irregular pieces.

For thin gauge sheeting installation drawings are necessary and shall as a minimum and as relevant specify:

a) type, thickness, material, length and designation of sheets;

b) type of fasteners and order (sequence) of fastenings including special installation notes for the type of fasteners (e.g. drilled hole diameter and minimum torque);

c) structural system for the sheeting;

d) seam and sidelap joints with specification of the type of fasteners and washers and sequence;

e) requirements for on-site manufacturing;

f) positions of all site connections not using pre-drilled holes;

g) type and details pertaining to the sub-assembly of the sheets, such as material, axial intervals, formation of supports, slope and details of eaves and verges;

h) expansion joints;

i) openings and necessary framing (e.g. lighting domes, smoke and heat ventilation installations and roof drainage);

j) mountings and attachments (e.g. for piping, cable conduits and sub-ceilings);

k) limitations of walkability during installation and requirements for load distributing devices.

9.6.2 Marking

Components that are individually assembled or erected at the site shall be allocated an erection mark.

A component shall be marked with its erected orientation if this is not clear from its shape.

NOTE Marks should be placed, if possible, in positions where they will be visible in storage and after erection.

Marking methods shall comply with 6.2.

9.6.3 Handling and storage on site

Handling and storage on site shall comply with the requirements of 6.3 and those given below.

Components shall be handled and stacked in such a way that the likelihood of damage is minimized. Particular attention shall be paid to slinging methods to avoid damage to the steelwork and protective treatment.

Steelwork damaged during off-loading, transportation, storage or erection shall be restored to conformity.

The procedure for restoration shall be defined before undertaking the repair. For EXC2, EXC 3 and EXC 4 the procedure shall also be documented.

Fasteners stored on site shall be kept in dry conditions prior to use and shall be suitably packed and identifiable.The fasteners shall be handled and used in accordance with the manufacturer's recommendations.

All small plates and other fittings shall be suitably packed and identified.

9.6.4 Trial erection

Any site trial erection shall be performed in accordance with the requirements of 6.10.

Trial erection should be considered:

a) to confirm fit between components;

b) to prove methodology if the erection sequence to maintain stability during erection needs evaluating in advance;

c) to prove duration of operations if site conditions are restricted by limited possession time.

9.6.5 Erection methods

9.6.5.1 General

The erection of the steelwork shall be carried out in conformity with the erection method statement and in such a way as to ensure stability at all times.

Foundation bolts shall not be used to secure unguyed columns against overturning unless they have been checked for this mode of use.

Throughout the erection of the structure, the steelwork shall be made safe against temporary erection loads, including those due to erection equipment or its operation and against the effects of wind loads on the unfinished structure.

For buildings, at least one third of the permanent bolts in each connection should be installed before that connection can be considered to contribute to stability of the part completed structure.

9.6.5.2 Temporary works

All temporary bracing and temporary restraints shall be left in position until erection is sufficiently advanced to allow its safe removal.

If it is required that bracings in tall buildings are to be de-stressed as erection progresses, to release the forces induced in them by vertical loads, this shall be carried out progressively one panel at a time. During such de-stressing sufficient alternative bracing shall be in place to ensure stability. If necessary, additional bracing shall be added temporarily for this purpose.

All connections for temporary components provided for erection purposes shall be made in accordance with the requirements of this European Standard and in such a way that they do not weaken the permanent structure or impair its serviceability.

If backing bars and draw cleats are used to support the structure during welding, it shall be ensured that they are sufficiently strong and that their retaining welds are appropriate for the erection load conditions.

If the erection procedure involves rolling or otherwise moving the structure, or part of the structure, into its final position after assembly, provision shall be made for controlled braking of the moving mass. Provision for reversing the direction of movement may need to be considered.

All temporary anchoring devices shall be made secure against unintentional release.

Only jacks that can be locked in any position under load shall be used unless other safety provisions are made.

9.6.5.3 Fit-up and alignment

Care shall be taken that no part of the structure is permanently distorted or over-stressed by stacking of steelwork components or by erection loads during the erection process.

Each part of the structure shall be aligned as soon as practicable after it has been erected and final assembly completed as soon as possible thereafter.

Permanent connections shall not be made between components until sufficient of the structure has been aligned, levelled, plumbed and temporarily connected to ensure that components will not be displaced during subsequent erection or alignment of the remainder of the structure.

Alignment of the structure and lack of fit in connections may be adjusted by the use of shims. Shims shall be secured where they are in danger of coming loose. For EXC3 and EXC4 securing of shims by welding is subjected to the requirements of Clause 7.

Shims shall be made of flat steel unless otherwise specified. Shims shall have similar durability to that of the structure. For stainless steel structures they shall be made of stainless steel and have a minimum thickness of 2 mm if used externally.

If shims are used to align structures composed of coated material, the shims shall be protected in a similar manner to provide the specified durability unless the shims are required to meet a specified friction classification.

Residual gaps for non-preloaded bolts and preloaded bolts before preloading shall be in accordance with 8.3 and 8.5.1 respectively.

If lack-of-fit between erected components cannot be corrected by the use of shims, components of the structure shall be locally modified in accordance with the methods specified in this European Standard. The modifications shall not compromise the performance of the structure in the temporary or permanent state. This work may be executed on site. Care shall be taken with structures built of welded latticed components and space structures to ensure that they are not subjected to excessive forces in an attempt to force a fit against their inherent rigidity.

Unless otherwise prohibited, drifts may be used to align connections. Elongation of holes for bolts used for transmission of loads shall not be more than the values given in 6.9.

In case of misalignment of holes for bolts, the method of correction shall be checked for consistency with the requirements of Clause 12.

Realigned holes may be proven to comply with the oversize or slotted hole requirements specified in 8.1 provided the load path has been checked.

Correction of misalignment by reaming or using a hollow milling cutter is preferred, but if the use of other cutting methods is unavoidable the internal finish of all holes formed by these other methods shall be specifically checked for consistency with the requirements of Clause 6.

Completed site connections shall be checked in accordance with 12.5.

10 Surface treatment

10.1 General

This clause specifies requirements for making steel surfaces with imperfections, including welded and fabricated surfaces, suitable for the application of paints and related products. The requirements to take account of the particular coating system to be applied shall be specified.

This clause does not deal with the detailed requirements for corrosion protection systems, which are specified in the following references that shall be applied as relevant:

a) surfaces to be painted: EN ISO 12944 series and Annex F;

b) surfaces to be metal coated by thermal spraying: EN 14616, EN 15311, EN ISO 14713 and Annex F;

c) surfaces to be metal coated by galvanizing: EN ISO 1461, EN ISO 14713 and Annex F.

For mechanical resistance and stability reasons there is no need for corrosion protection if the structure is to be used for a short service lifetime, or in an environment with negligible corrosivity (e.g. category C1 or painting for aesthetic purposes only), or has been dimensioned to allow for corrosion.

NOTE 1 A year may be considered as a short service lifetime.

If painting is specified for aesthetic reasons Table 22 together with Annex F are applicable.

If both a fire protection and corrosion protection systems are specified, they shall be proven to be compatible.

NOTE 2 Fire protection is not generally considered to be a part of the corrosion protection.

10.2 Preparation of steel substrates

These requirements do not apply to stainless steels. If there are requirements for surface cleanliness of stainless steels, they shall be specified.

All surfaces to which paints and related products are to be applied shall be prepared to meet the criteria of EN ISO 8501. The preparation grade according to EN ISO 8501-3 shall be specified.

If the expected life of the corrosion protection and corrosivity category are specified, the preparation grade shall be in accordance with Table 22.

Table 22 — Preparation grade

Expected life of the corrosion protection [a]	Corrosivity category [b]	Preparation grade [c]
> 15 years	C1 / C2	P1
	Above C2	P2
5 years to 15 years	C1 to C3	P1
	Above C3	P2
< 5 years	C1 to C4	P1
	C5 – Im	P2

[a] [b] Expected life of the corrosion protection and corrosivity category are referenced in EN ISO 12944 and EN ISO 14713 as relevant.

[c] Preparation grade P3 may be specified for special cases.

Thermally cut surfaces, edges and welds shall be suitably smooth and able to achieve the specified roughness after subsequent surface preparation (see Annex F).

NOTE Thermally cut surfaces are sometimes too hard for the abrasive material to achieve the suitable surface roughness. The procedure test specified in 6.4.4 may be used to establish surface hardness and determine whether grinding is necessary.

10.3 Weather resistant steels

If necessary, procedures to ensure that the surface of uncoated weather resistant steels is acceptable visually after weathering shall be specified together with procedures to prevent contamination (e.g. from oil, grease, paint, concrete or asphalt).

NOTE As an example, exposed areas may need to be blast cleaned to ensure uniform weathering.

The treatment necessary for surfaces of non-weather resistant steels if these are in contact with uncoated weather resistant steels shall be specified.

10.4 Galvanic coupling

Unintended contact between different metallic constituent products, e.g. stainless steels to aluminium or structural steel shall be avoided. If stainless steel is to be welded to structural steel, corrosion protection for the steel structure shall continue from the weld on to the stainless steel by 20 mm as a minimum. See also 6.3, 6.9 and 7.7.3.

10.5 Galvanizing

If pickling is to be used prior to galvanizing, all weld gaps should be sealed prior to pickling to prevent the ingress of acid, unless this conflicts with considerations set out in 10.6 below.

If the fabricated component contains enclosed spaces, vent and drain holes shall be provided. The enclosed space shall generally be galvanized internally and if not it shall be specified whether these enclosed spaces shall be sealed after galvanizing and, if so, with what.

10.6 Sealing of spaces

If enclosed spaces are to be sealed by welding or provided with internal protective treatment, the internal treatment system shall be specified.

If spaces are to be fully enclosed by welds, it shall be specified if weld imperfections permitted under the welding specification require sealing by application of suitable filler material to prevent the ingress of moisture. If welds are for sealing purposes only, those welds shall be visually inspected. If required, further inspection shall be specified.

NOTE Attention is drawn that cracks in welds, which are not detectable by visual inspection, can allow water to penetrate the sealed space.

If closed sections are to be galvanized, they shall not be sealed before galvanizing. In the case of overlapping surfaces with continuous welds, adequate venting shall be provided, unless the area of overlap is so small that the risk of explosive egress of entrapped gases during the galvanizing operation is assessed as not significant.

If mechanical fasteners penetrate the wall of sealed enclosed spaces, the method to be used for sealing the interface shall be specified.

10.7 Surfaces in contact with concrete

Surfaces that are to be in contact with concrete including the undersides of baseplates shall be coated with the protective treatment applied to the steelwork, excluding any cosmetic finishing coat, for a minimum of the first 50 mm of the embedded length unless otherwise specified and the remaining surfaces need not be coated unless specified. If uncoated, such surfaces shall be blast cleaned or wire-brushed to remove loose mill scale and cleaned to remove dust, oil and grease. Immediately before concreting, any loose rust, dust and other loose debris shall be removed by cleaning.

10.8 Inaccessible surfaces

Areas and surfaces that are difficult to access after assembly should be treated before assembly.

In slip resistant connections, faying surfaces shall meet the requirements necessary to develop the friction for the specified surface treatment (see 8.4). Other connections shall not be made with excess paint on the faying surfaces. As a maximum, faying surfaces and surfaces beneath washers shall be treated with a primer and undercoat unless specified otherwise (see F.4).

Unless specified otherwise, bolted connections including the perimeter around such connections shall be treated with the full corrosion protection system specified for the remainder of the steelwork.

10.9 Repairs after cutting or welding

It shall be specified if repair, or additional protective treatment, is required to cut edges and adjacent surfaces after cutting.

If precoated constituent products are to be welded, the methods and extent of repair necessary to the coating shall be specified.

If galvanizing to surfaces has been removed or damaged by welding, the surfaces shall be cleaned, prepared and treated with a zinc rich primer and paint system offering a similar level of corrosion protection as the galvanizing for the given corrosivity category (see EN ISO 1461 for additional guidance).

10.10 Cleaning after erection

10.10.1 Cleaning of thin gauge components

The structure shall be cleaned daily from stems of blind rivets, drill-shavings etc., to prevent damage by corrosion.

10.10.2 Cleaning of stainless steels components

Cleaning procedures shall be appropriate for the grade of constituent product, surface finish, function of the component and corrosion risk. The method, level and extent of cleaning shall be specified.

Strong acid solutions sometimes used to clean the masonry and tiling of buildings shall not be permitted to come into contact with structural steel, including stainless steel. If such contamination does happen, acid solutions shall be washed off immediately with large amounts of clean water.

11 Geometrical tolerances

11.1 Tolerance types

This clause defines the types of geometrical deviations and gives quantitative values for two types of permitted deviations:

a) those applicable for a range of criteria that are essential for the mechanical resistance and stability of the completed structure, called essential tolerances;

b) those required to fulfil other criteria such as fit-up and appearance, called functional tolerances.

Essential tolerances and functional tolerances are both normative.

NOTE For structural steel components, prEN 1090-1 refers to the essential tolerances.

The permitted deviations given do not include elastic deformations induced by the self-weight of the components.

In addition, special tolerances may be specified either for geometrical deviations already defined with quantitative values or for other types of geometrical deviations. If special tolerances are required the following information shall be given as appropriate:

— amended values for functional tolerances already defined;

— defined parameters and permitted values for the geometrical deviations to be controlled;

— whether these special tolerances apply to all relevant components or only to particular components that are specified.

In each case, the requirements are for final acceptance testing. If fabricated components are to form parts of a structure that is to be erected on site, the tolerances specified for the final checking of the erected structure shall be met in addition to those for the fabricated components.

11.2 Essential tolerances

11.2.1 General

Essential tolerances shall be in accordance with D.1. The values specified are permitted deviations. If the actual deviation exceeds the permitted value, the measured value shall be dealt with as a nonconformity according to Clause 12.

In some cases there is a possibility that the uncorrected deviation of an essential tolerance can be justified in accordance with the structural design when the excess deviation is included explicitly in a recalculation. If not, the nonconformity shall be corrected.

11.2.2 Manufacturing tolerances

11.2.2.1 Rolled sections

Hot rolled, hot finished or cold formed structural products shall conform to the permitted deviations specified by the relevant product standard. These permitted deviations continue to apply to components manufactured from such products, unless superseded by more stringent criteria specified in D.1.

11.2.2.2 Welded sections

Welded components manufactured from plates shall conform to the permitted deviations in Table D.1.1 and Tables D.1.3 to D.1.6.

11.2.2.3 Cold formed sections

Components cold formed by pressing shall conform to the permitted deviations in Table D.1.2. For components fabricated from rolled cold formed sections, see 11.2.2.1.

NOTE As examples, cross-sectional tolerances for welded sections manufactured from split rolled sections would be in accordance with the relevant product standard except for overall depth and web geometry which should be in accordance with Table D.1.1; and cross sectional tolerances from EN 10162 apply to cold rolled sections whereas Table D.1.2 applies to sections formed by pressing.

11.2.2.4 Stiffened plating

Stiffened plating shall conform to the permitted deviations in Table D.1.6.

11.2.2.5 Profiled sheets

Profiled sheets used as structural components shall conform to the permitted deviations specified in EN 508-1 and EN 508-3 plus those in Table D.1.7.

11.2.2.6 Shells

Shell structures shall conform to the permitted deviations in Table D.1.9, in which the choice of the appropriate class shall be based on EN 1993-1-6.

11.2.3 Erection tolerances

11.2.3.1 Reference system

Deviations of erected components shall be measured relative to their position points (see ISO 4463). If a position point is not established, deviations shall be measured relative to the secondary system.

11.2.3.2 Foundation bolts and other supports

The position of the centre points of a group of foundation bolts or other support shall not deviate by more than ± 6 mm from its specified position relative to the secondary system.

A best-fit position should be chosen to assess a group of adjustable foundation bolts.

11.2.3.3 Column bases

Holes in baseplates and other plates used for fixing to supports should be dimensioned to allow clearances to match the permitted deviations for the supports to those for the steelwork. This may require the use of large washers between the nuts on the holding down bolts and the top of the baseplate.

11.2.3.4 Columns

The deviations of erected columns shall conform to the permitted deviations in Tables D.1.10 to D.1.11.

For groups of adjacent columns (other than those in portal frames or supporting a crane gantry) carrying similar vertical loads, the permitted deviations shall be as follows:

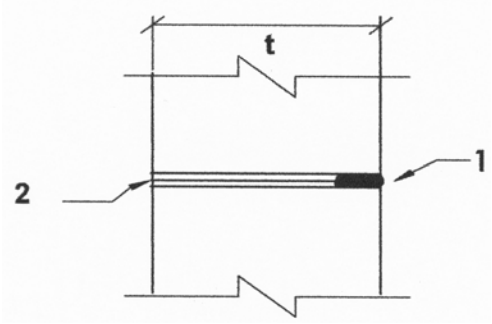
a) the arithmetic average deviation in plan for the inclination of six tied adjacent columns shall conform to the permitted deviations in Tables D.1.10 to D.1.11;

b) the permitted deviations for the inclination of an individual column within this group, between adjacent storey levels may then be relaxed to $\Delta = \pm h/100$.

11.2.3.5 Full contact bearing

Where full contact bearing is specified, the fit-up between surfaces of erected components shall be in accordance with Table D.1.12 after alignment.

For bolted splices shims may be used where the gap exceeds the specified limits after initial bolting-up, to reduce the gaps to within the permitted deviation, unless otherwise specified in the execution specification. The shims may be made of flat mild steel. No more than three shims shall be used at any point. If necessary, the shims may be held in place by means of either fillet welds or a partial penetration butt weld extending over the shims, as shown in Figure 7.



Key

1 partial penetration butt weld or fillet weld

2 shims

Figure 7 — Option for securing shims used for bolted splice in full contact bearing

11.3 Functional tolerances

11.3.1 General

Functional tolerances in terms of accepted geometrical deviations shall be in accordance with one of the following two options:

a) the tabulated values described in 11.3.2, or

b) the alternative criteria defined in 11.3.3.

If no option is specified the tabulated values shall apply.

11.3.2 Tabulated values

Tabulated values for functional tolerances are given in D.2. Generally values for two classes are shown. The choice of tolerance class may be applied to individual components or selected parts of an erected structure.

NOTE How D.2 can be applied would be to invoke tolerance class 2 for part of a structure to which a glazed facade was to be fitted, in order to reduce the amount of clearance and adjustability required at the interface.

If D.2 is used, and the choice of class is not specified, tolerance class 1 applies.

In applying Table D.2.19, the protruding length of a vertical foundation bolt (in its best-fit position if adjustable) should be vertical to within 1 mm in 20 mm. A similar requirement would apply to the line of bolts set horizontally or at other angles.

11.3.3 Alternative criteria

If specified the following alternative criteria may be applied:

a) for welded structures, the following classes according to EN ISO 13920 apply:

   1) class C for length and angular dimensions;

   2) class G for straightness, flatness and parallelism;

b) for non-welded components the same criteria as in (a);

c) in other cases, for a dimension d, a permitted deviation $\pm \Delta$ equal to the greater of d/500 or 5 mm is allowed.

12 Inspection, testing and correction

12.1 General

This clause specifies the requirements for inspection and testing with respect to the quality requirements included in quality documentation (see 4.2.1) or quality plan (see 4.2.2) as relevant.

Inspection, testing and corrections shall be undertaken on the works against the specification and within the quality requirements set out in this European Standard.

All inspection and testing shall be undertaken to a predetermined plan with documented procedures. Specific inspection testing and associated corrections shall be documented.

12.2 Constituent products and components

12.2.1 Constituent products

Documents supplied with constituent products in accordance with the requirements of Clause 5 shall be checked to verify that the information on the products supplied matches those ordered.

NOTE 1 These documents include inspection certificates, test reports, declaration of compliance as relevant for plates, sections, hollow sections, welding consumables, mechanical fasteners, studs etc.

NOTE 2 This documentation check is intended to obviate the need for testing products generally.

The inspection of the surface of product for defects revealed during surface preparation shall be included in the inspection and test plans.

If surface defects in steel products revealed during surface preparation are repaired using methods that are in accordance with this European Standard, the repaired product may be used provided that it complies with the nominal properties specified for the original product.

There are no requirements for specific testing of products unless otherwise specified.

12.2.2 Components

Documents supplied with components shall be checked to verify that the information on the components supplied matches those ordered.

NOTE This applies to all delivered and part-fabricated products received into a constructor's works for further processing (e.g. welded I-sections for incorporation into plate girders), and to products received on site for erection by the constructor if these are not manufactured by the constructor.

12.2.3 Non conforming products

If the documentation supplied does not include a declaration from the supplier that the products conform to the specifications, they shall be treated as non conforming products until it can be demonstrated that they meet the requirements of the inspection and test plan.

If products are first designated as nonconforming and are subsequently proved to be in conformity by test or retest, the testing shall be recorded.

12.3 Manufacturing: geometrical dimensions of manufactured components

The inspection plan shall consider the requirements and the checks necessary on prepared constituent steel products and manufactured components.

Dimensional measurements of components shall always be taken. Methods and instruments used shall be selected, as appropriate, from those listed in ISO 7976-1 and ISO 7976-2. Accuracy shall be assessed in accordance with the relevant part of ISO 17123.

The location and frequency of measurements shall be specified in the inspection plan.

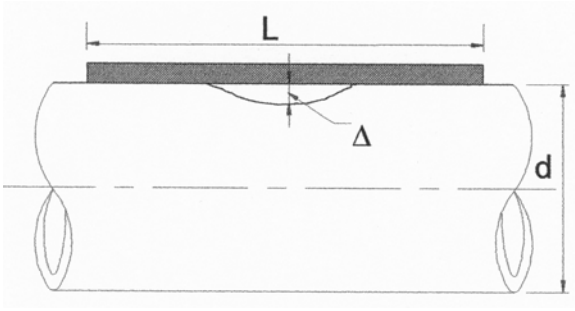
The acceptance criteria shall be in accordance with 11.2. The deviations shall be measured with respect to any specified camber or preset.

If acceptance inspection results in the identification of nonconformity, the action on such nonconformity shall be as follows:

a) if practicable, the nonconformity shall be corrected using methods that are in accordance with this European Standard and checked again;

b) if correction is not practicable, modifications to the steel structure may be made to compensate for the nonconformity provided that this is in accordance with a procedure for handling nonconformities.

Damage resulting in local dents in the surface of hollow sections shall be assessed. The method shown in Figure 8 may be used.



Characteristic cross-sectional dimension of section is d
Straight edge of length L ≥ 2d Gap Δ ≤ the larger of *d*/100 or 2 mm

Figure 8 — Method of assessment for surface profile and permitted deviation of a dented component

If the gap exceeds the permitted deviation, repairs may be executed by means of fully welding on local cover plates of the same thickness as the original constituent product unless otherwise specified.

NOTE Such repairs are not uncommon, because many hollow sections have relatively thin walls.

This procedure should be used in preference to any hot-shaping procedure in accordance with 6.5.

If trial assembly to 6.10 is used the inspection requirements shall be included in the inspection plan.

12.4 Welding

12.4.1 Inspection before and during welding

Inspection before and during welding shall be included in the inspection plan according to the requirements given in the relevant part of EN ISO 3834.

Non destructive testing (NDT) methods shall be selected in accordance with EN 12062 by personnel qualified according to Level 3 as defined in EN 473. Generally ultrasonic testing or radiographic testing applies to butt welds and penetrant testing or magnetic particle inspection applies to fillet welds.

NDT, with the exception of visual inspection, shall be performed by personnel qualified according to Level 2 as defined in EN 473.

If the inspection plan requires a check of the fit-up before the welding of hollow sections prepared for branch welding, the following locations shall be given particular attention:

— for circular sections: the mid-toe, mid-heel and two mid-flank positions;

— for square or rectangular sections: the four corner positions.

12.4.2 Inspection after welding

12.4.2.1 Timing

The supplementary NDT of a weld shall generally not be completed until after the minimum hold time after welding shown in Table 23.

Table 23 — Minimum hold times

Weld size (mm) [a]	Heat input *Q* (kJ/mm) [b]	Hold time (hours) [c]	
		S235 to S420	S460 and above
a or *s* ≤ 6	All	Cooling period only	24
6 < *a* or *s* ≤ 12	≤ 3	8	24
	> 3	16	40
a or *s* > 12	≤ 3	16	40
	> 3	40	48

[a] Size applies to the nominal throat thickness *a* of a fillet weld or the nominal material thickness *s* of a full penetration weld. For individual partial penetration butt welds the governing criterion is the nominal weld depth *a*, but for pairs of partial penetration butt welds welded simultaneously it is the sum of the weld throats *a*.

[b] Heat input *Q* to be calculated in accordance with Clause 19 of EN 1011-1:1998.

[c] The time between weld completion and commencement of NDT shall be stated in the NDT report. In the case of “cooling period only” this will last until the weld is cool enough for NDT to commence.

For welds requiring preheat, these periods may be reduced if the weldment is post-heated for a period after welding is complete in accordance with Annex C of EN 1011-2:2001.

If a weld will become inaccessible through subsequent work, it shall be inspected prior to subsequent work being carried out.

Any weld located in a zone where unacceptable distortion has been corrected shall be inspected again.

12.4.2.2 Scope of inspection

All welds shall be visually inspected throughout their entire length. If surface imperfections are detected, surface testing by penetrant testing or magnetic particle inspection shall be carried out on the inspected weld.

Unless otherwise specified no supplementary NDT is required for EXC1 welds. For EXC2, EXC3 and EXC4 welds the extent of supplementary NDT is as specified below.

The extent of NDT covers both testing of surface or internal imperfections if applicable.

For the first 5 joints made to the same new WPS the following requirements shall be fulfilled:

a) the quality level B is required for demonstration of the WPS in production conditions;

b) the % to be tested shall be double of the values in Table 24 (max. 100 %);

c) the minimum length to be inspected is 900 mm.

If inspection gives non conforming results, investigation shall be carried out in order to find the reason and a new set of five joints shall be tested. The guidance in Annex C of EN 12062:1997 should be followed.

NOTE 1 The purpose of the inspection described above is to establish that with a WPS can be produced conforming quality when implemented in production. For development and use of a WPS see flow diagram in Annex L.

Once it has been established that production welding according to a WPS meets the quality requirements, the required extent of supplementary NDT shall be in accordance with Table 24 with further joints welded according to the same WPS treated as a single continuing inspection lot. The percentages apply to the extent of supplementary NDT treated as the cumulative amount within each inspection lot.

The joints for inspection according to Table 24 shall be selected on the basis of Annex C of EN 12062:1997, with a minimum total length for an inspection lot *x* of 900 mm, ensuring that sampling covers the following variables as widely as possible: the joint type, the constituent product grade, the welding equipment and the work of the welders. The execution specification may identify specific joints for inspection together with the extent and method of testing.

If inspection discovers weld defects within an inspection length in excess of the requirements specified in the acceptance criteria, inspection shall be undertaken over two inspection lengths, one on each side of the length including the defect. If inspection on one or other side gives non conforming results, investigation shall be carried out in order to find the reason.

NOTE 2 The purpose of the inspection in Table 24 is to establish that ongoing production is producing conforming welds.

Table 24 — Extent of supplementary NDT

Type of weld	Shop and site welds		
	EXC2	EXC3	EXC4
Transverse butt welds and partial penetration welds in butt joints subjected to tensile stress:			
$U \geq 0,5$	10 %	20 %	100 %
$U < 0,5$	0 %	10 %	50 %
Transverse butt welds and partial penetration welds:			
in cruciform joints	10 %	20 %	100 %
in T joints	5 %	10 %	50 %
Transverse fillet welds in tension or shear:			
With $a > 12$ mm or $t > 20$ mm	5 %	10 %	20 %
With $a \leq 12$ mm and $t \leq 20$ mm	0 %	5 %	10 %
Longitudinal welds and welds to stiffeners	0 %	5 %	10 %

NOTE 1 Longitudinal welds are those made parallel to the component axis. All the others are considered as transverse welds.

NOTE 2 U = Utilization grade for welds for quasi-static actions. $U = E_d/R_d$, where E_d is the largest action effect of the weld and R_d is the resistance of the weld in the ultimate limit state.

NOTE 3 Terms a and t refer respectively to the throat thickness and the thickest material being joined.

12.4.2.3 Visual inspection of welds

The visual inspection shall be performed after completion of welding in an area and before any other NDT inspection is carried out.

Visual inspection shall include:

a) the presence and location of all welds;

b) inspection of the welds in accordance with EN 970;

c) stray arcs and areas of weld spatter.

The inspection of the shape and surface of welds of welded branch joints using hollow sections shall pay careful attention to the following locations:

a) for circular sections: the mid-toe, mid-heel and two mid-flank positions;

b) for square or rectangular sections: the four corner positions.

12.4.2.4 Additional NDT methods

The following NDT methods shall be carried out in accordance with the general principles given in EN 12062 and with the requirements of the standard particular to each method:

a) penetrant testing (PT) according to EN 571-1;

b) magnetic particle inspection (MT) according to EN 1290;

c) ultrasonic testing (UT) according to EN 1714, EN 1713;

d) radiographic testing (RT) according to EN 1435.

The field of application of NDT methods is specified in their relevant standards.

12.4.2.5 Correction of welds

For EXC2, EXC3 and EXC4, repairs by welding shall be carried out in accordance with qualified welding procedures.

Corrected welds shall be checked and shall meet the requirements of the original welds.

12.4.3 Inspection and testing of welded shear studs for composite steel and concrete structures

Inspection and testing of welded shear studs for composite steel and concrete structures shall be carried out according to EN ISO 14555.

This inspection includes checking the length of the studs after welding.

Non conforming studs shall be replaced. It is recommended that replacement studs be welded in an adjacent new position.

The proper operation of welding equipment used on site should be rechecked after it has been moved and at the commencement of each shift or other period of work by using tests on studs welded with the equipment in accordance with EN ISO 14555.

12.4.4 Production tests on welding

If specified, for EXC3 and EXC4, production tests shall be carried out as follows:

a) each welding procedure qualification used for welding steel grades higher than S460 shall be checked with a production weld. Testing includes visual examination, penetrant testing or magnetic particle inspection, ultrasonic testing or radiographic testing (for butt welds), hardness testing and macroscopic examination. The tests and results shall be in accordance with the relevant standard for welding procedure test;

b) if the deep penetration of a welding process is used for fillet welds, the penetration of the welds shall be checked. The results of the actual penetration shall be documented;

c) for bridge deck orthotropic steel plates:

   1) stiffener to deckplate connections welded by fully mechanized welding process shall be checked with a production test for each 120 m length of bridge, with a minimum of one production test for a bridge, and inspected by macro-examination. Macro section tests shall be prepared at start or stop and at the middle of the weld;

   2) stiffener to stiffener connections with splice plates shall be checked with a production test.

12.5 Mechanical fastening

12.5.1 Inspection of non-preloaded bolted connections

All connections with non-preloaded mechanical fasteners shall be visually checked after they are bolted up with the structure aligned locally.

Connections identified during snagging that do not have a full complement of bolts shall be checked for fit up after the missing bolts have been installed.

Acceptance criteria and action to correct nonconformity shall be in accordance with 8.3 and 9.6.5.3.

If the nonconformity is due to differing ply thickness that exceeds the criteria specified in 8.1, the connection shall be remade. Otherwise nonconformity may be corrected, if possible, by adjusting the local alignment of the component.

Corrected connections shall be checked again on re-completion.

If an insulation system is required at junctions between stainless steel and other metals, the requirements for checking the installation shall also be specified.

12.5.2 Inspection and testing of preloaded bolted connections

12.5.2.1 Inspection of friction surfaces

If the connections incorporate friction surfaces the surfaces shall be visually checked immediately before assembly. Acceptance criteria shall be in accordance with 8.4. Nonconformities shall be corrected in accordance with 8.4.

If preloaded bolts are used for stainless steel connections, the requirements for inspection and testing shall be specified.

12.5.2.2 Inspection before tightening

All connections with preloaded mechanical fasteners shall be visually checked after they are initially bolted up with the structure aligned locally and before the commencement of preloading. Acceptance criteria shall be in accordance with 8.5.1.

If the nonconformity is due to differing ply thickness that exceeds the criteria specified in 8.1, the connection shall be remade. Otherwise nonconformity may be corrected, if possible, by adjusting the local alignment of component.

If chamfered washers are installed then they shall be visually checked to ensure that assembly is in accordance with 8.2.4 and Annex J.

Corrected connections shall be checked on re-completion.

For EXC2, EXC3 and EXC4, the tightening procedure shall be checked. If tightening is carried out by the torque method or the combined method, the torque wrench calibration certificates shall be checked to verify the accuracy to 8.5.1.

12.5.2.3 Inspection during and after tightening

In addition to the following general requirements for inspection, which apply to all tightening methods except for the HRC method, particular requirements are given in 12.5.2.4 to 12.5.2.7.

For EXC2, EXC3 and EXC4, inspection during and after tightening shall be carried out as follows:

a) inspection of installed fasteners and/or methods of installation shall be undertaken depending on the tightening method used. The locations selected shall be on a random basis ensuring that the sampling covers the following variables as appropriate - connection type; bolt group, fastener lot, type and size; equipment used and the operatives;

b) for the purposes of the inspection, a bolt group is defined as bolt assemblies of the same origin in similar connections with the bolt assemblies of the same size and class. A large bolt group may be subdivided into a number of subgroups for inspection purposes;

c) the number of bolt assemblies inspected overall in a structure shall be as follows:

— EXC2: 5 % for the second step of the torque or the combined method and for the DTI method;

— EXC3 and EXC4:

i. 5 % for the first step and 10% for the second step of the combined method;

ii. 10 % for the second step of the torque method and for the DTI method;

d) unless otherwise specified, the inspection shall be carried out using a sequential sampling plan according to Annex M for a sufficient number of bolt assemblies until either the acceptance or the rejection conditions (or all assemblies have been tested) for the relevant sequential type are met for the relevant criteria. The sequential types shall be as follows:

— EXC2 and EXC3: sequential type A;

— EXC4: sequential type B;

e) the pretightening step shall be checked by visual inspection of connections to ensure they are fully packed;

f) for final tightening inspection the same bolt assembly shall be used for checking both under-tightening and, if specified, over-tightening;

g) for the inspection of pretightening only the under-tightening criterion is to be checked;

h) the criteria defining a nonconformity and requirements for corrective action are specified below for each tightening method;

i) if the inspection leads to a rejection, all the bolting assemblies in the bolt subgroup shall be checked and corrective actions shall be taken. If the result of inspection when using a sequential type A is negative, the inspection may be enlarged to the sequential type B;

j) after completion a new inspection is required.

If fasteners are not applied in accordance with the defined method, the removal and re-installation of the whole bolt group shall be witnessed.

12.5.2.4 Torque method

The inspection of a bolt assembly shall be carried out, using Table 25, by the application of a torque to the nut (or to the bolt head if specified) using a calibrated torque wrench. The objective is to check that the torque value necessary to initiate rotation is at least equal to 1,1 times the torque value $M_{r,i}$ (i.e $M_{r,2}$ or $M_{r,\,test}$). Caution shall be taken to keep the rotation to a strict minimum. The following conditions apply:

a) the torque wrench used for the inspections shall be correctly calibrated and have an accuracy of $\pm$ 4 %;

b) the inspection shall be carried out between 12 h and 72 h after final completion of tightening in the bolt subgroup concerned;

NOTE 1 If the bolt assemblies to be inspected are from different assembly lots, with inspection torque values that are different the locations of each lot should be established.

NOTE 2 If the contact surfaces are protection-coated, in particular if painted, the loss of preload can be such that the satisfying of the criteria specified is not possible. Special inspection procedures, such as continuous supervision of tightening, can be necessary in these circumstances.

c) if the result is rejection, the accuracy of torque wrench used for tightening shall be checked.

Table 25 — Inspection of tightening by the torque method

Execution Class	At start of tightening	After tightening
EXC2	- Identification of assembly bolt lot locations	Inspection of the second tightening step
EXC3 and EXC4	- Identification of assembly bolt lot locations, - checking the bolt tightening procedure for each bolt group.	Inspection of the second tightening step
NOTE For assembly bolt lot definition, see EN 14399-1.		

A bolting assembly for which the nut turns by more than 15° by the application of the inspecting torque is considered to be under-tightened (< 100 %) and shall be retightened up to 100 % of the required torque.

12.5.2.5 Combined method

For EXC3 and EXC4 the first step shall be controlled before marking using the same torque conditions as used to reach the 75 % condition. A bolt which turns by more than 15° by the application of the inspecting torque is considered defective and shall be retightened.

If the connections are not fully packed according to 8.3 and 8.5.1, the calibrations of the torque wrenches in combination with the applied loads shall be controlled by supplementary tests to achieve the correct initial pretightening load. If necessary, the first step has to be repeated with the corrected torque values.

If still unpacked, the thickness and out of plane of the assembled connections shall be inspected and adjusted.

Before the second step starts, the markings of all the nuts relative to the bolt threads shall be visually inspected. Any mark missing shall be corrected.

After the second step, the marks shall be inspected with the following requirements:

a) if the rotation angle is more than 15° below the specified value, this angle shall be corrected;

b) if the rotation angle is more than 30° over the specified angle, or the bolt or the nut has failed, the bolt assembly shall be replaced by new one.

12.5.2.6 HRC method

The inspection shall be carried out on 100 % of the bolting assemblies by visual inspection. Fully tightened bolt assemblies are identified as those with the spline end sheared off. A bolt assembly for which the spline end remains is considered to be under-tightened.

If tightening of HRC bolting assemblies is completed using the torque method according to 8.5.3 or by the DTI method to 8.5.6, they shall be inspected according to 12.5.2.4 or 12.5.2.7 as appropriate.

12.5.2.7 Direct tension indicator method

After the pretightening step, connections shall be inspected to ensure that they are properly packed in accordance with 8.3. The local alignment of non conforming connections shall be corrected before final tightening commences.

After final tightening, assemblies selected for inspection in accordance with 12.5.2.3 shall be checked to establish that the final indicator settings are in accordance with the requirements in Annex J. The visual inspection shall include a check to identify any indicators that exhibit full compression of the indicator. No more than 10 % of the indicators in a connection bolt group shall exhibit full compression of the indicator.

If the fasteners are not installed in accordance with Annex J or if the final indicator setting is not within the specified limits, the removal and reinstallation of the non conforming assembly shall be supervised, and the whole bolt group shall then be inspected. If the direct tension indicator has not been tightened to the specified limit, the assembly can be further tightened until this limit is achieved.

12.5.3 Inspection, testing and repairs of hot rivets

12.5.3.1 Inspection

The number of rivets inspected overall in a structure shall be at least 5 %, with a minimum of 5.

Heads of driven rivets shall be visually inspected and shall satisfy the acceptance criteria of 8.7.

Inspection of satisfactory contact shall de done by lightly ringing the rivet head with a hammer of 0,5 kg. The inspection is carried out using a sequential sampling plan according to Annex M to a sufficient number of rivets until either the acceptance or the rejection conditions for the relevant sequential type are met for the relevant criteria. The sequential types are as follows:

— EXC2 and EXC3: sequential type A;

— EXC4: sequential type B.

If the inspection leads to a rejection, all the rivets shall be checked and corrective actions shall be taken.

12.5.3.2 Repairs

If it is necessary to replace a defective rivet, it shall be done before the structure is loaded. Cutting out shall be done by means of a chisel or by cutting.

After removing a rivet, sides of the rivet hole shall be inspected carefully. In case of cracks, pits, or hole distortion, the hole shall be reamed. If necessary, the replacement rivet shall be of a larger diameter than that removed.

12.5.4 Inspection of cold formed components and sheeting fastening

12.5.4.1 Self-tapping and self-drilling screws

If using self-tapping screws, sample holes shall be measured periodically by spot checks on site to ensure that they are in accordance with the fastener manufacturer's recommendations.

If using self-drilling and self-tapping screws on site, sampler screws shall be spot checked periodically to ensure thread integrity after setting. This method is advisable for each different application. Fasteners which

exhibit a deformation of thread form exceeding the limits given by the fastener manufacturer shall be treated as nonconforming and be replaced with new fasteners.

NOTE The advice of the fastener manufacturer should be sought in respect of replacement fasteners. These can need to be of a larger diameter to ensure a secure fixing in a pre-formed hole.

12.5.4.2 Blind rivets

Sample holes shall be measured periodically by spot checks on site to ensure that they are in accordance with the product manufacturer's recommendations.

Holes with burred edges that would adversely affect the drawing together of the connected parts shall be treated as nonconforming until such time as they are rectified.

Connections with blind rivets shall be inspected to ensure that the upset at the blind end of the rivet is not formed between the overlapping sheets. Such connections shall be treated as nonconforming. The spoilt rivet shall be removed and replaced.

If the spoilt rivet is removed with a drill of larger diameter than used to form the original hole the replacement rivet shall be suitable for the hole size created.

12.5.5 Special fasteners and fastening methods

12.5.5.1 General

Requirements for inspection of connections using special fasteners or special fastening methods in accordance with 8.9 shall be specified.

If tapped holes are used in cast materials, NDT around the tapped holes shall be carried out to ensure material homogeneity.

12.5.5.2 Cartridge fired and air driven pins

Inspection shall be carried out to ensure that cartridge fired and air driven pins connections have not been over or underdriven.

NOTE If too powerful a power load is used there may be heavy indentation or excessive deformation of the washers (overdriving). Insufficient penetration of the fastener is due to use of too light driving force (underdriving).

The manufacturer's identification mark on the pin shall still be recognizable after the fasteners have been driven.

12.5.5.3 Other mechanical fasteners

Inspection of connections with other mechanical fasteners (such as, e.g. hook-bolts, special fasteners) shall be applied according to national product standards/recommendations or manufacturers guidelines or specified methods.

12.6 Surface treatment and corrosion protection

If the structure is to be protected against corrosion, inspection of the structure prior to corrosion protection shall be carried out against the requirements of Clause 10.

All surfaces, welds and edges shall be visually inspected.The acceptance criteria shall meet requirements of EN ISO 8501.

Nonconforming components shall be retreated, retested and re-inspected afterwards.

The inspection of the corrosion protection shall be carried out according to Annex F.

12.7 Erection

12.7.1 Inspection of trial erection

Requirements for inspection of any trial erection to 9.6.4 shall be specified.

12.7.2 Inspection of the erected structure

The condition of the erected structure shall be inspected for any indication that components have been distorted or overstressed, and to ensure that any temporary attachments have either been removed satisfactorily or are in accordance with the specified requirements.

12.7.3 Survey of geometrical position of connection nodes

12.7.3.1 Survey methods and accuracy

A survey of the completed structure shall be made. This survey shall be related to the secondary net. For EXC3 and EXC4 this survey shall be recorded; if there is a requirement to record dimensional checks at acceptance of the structure, this shall be specified.

Methods and instruments used shall be selected from those listed in ISO 7976-1 and ISO 7976-2. The selection shall take into account the capability of the survey process in terms of accuracy relative to the acceptance criteria. If appropriate, the survey shall be corrected for the effects of temperature and the accuracy of the measurements relative to that in 9.4.1 shall be estimated according to the relevant parts of ISO 17123.

NOTE In most cases where surveys take place in ambient temperatures between 5 °C and 15 °C no correction is necessary.

12.7.3.2 System of measurement

The system of permitted deviations is built up from position points at base level, an envelope for column verticality and a series of intermediate and roof levels referred to as-built floor levels.

NOTE Position points mark the location of individual components for instance columns (see ISO 4463-1).

Each individual value shall be in accordance with the values from the figures and tables. The algebraic sum of the discrete values shall not be greater than the permitted deviations for the total structure.

The system shall set out requirements for connection positions. Between these positions the manufacturing tolerances define permitted deviations.

The system does not set out explicit requirements for secondary structural components such as side posts and purlins.

Special attention will need to be given to establishing lines and levels when fitting to existing construction.

12.7.3.3 Reference points and levels

Erection tolerances shall generally be specified relative to the following reference points on each component:

a) for components within 10° of the vertical: the centre of the component at each end;

b) for components within 45° of the horizontal (including the tops of lattice trusses): the centre of the top surface at each end;

c) for internal components in built-up lattice girders and trusses: the centre of the component at each end;

d) for other components: the erection drawings shall indicate the reference points which shall generally be the top or outside surfaces of components mainly subject to bending and centre lines of components mainly subject to direct compression or tension.

Alternative reference points may be substituted for ease of reference, provided that they have similar effect to those specified above.

12.7.3.4 Location and frequency

Measurements will only be taken of the position of components adjacent to site interconnection nodes as set out below, unless otherwise specified. The location and frequency of measurements shall be specified in the inspection plan.

NOTE Critical dimensional checks of the as-built structure necessary in relation to special tolerances should be identified and these should be incorporated into the inspection plan.

The positional accuracy of the erected steelwork should be measured under self weight of steelwork only unless otherwise specified. The conditions under which the measurements shall take place shall then be specified as well as the deviations and movements due to imposed loads, other than those due to self weight of steelwork, if these can affect dimensional checks.

12.7.3.5 Acceptance criteria

The acceptance criteria are given in 11.2 and 11.3.

12.7.3.6 Definition of nonconformity

Assessment of whether a non conformity exists shall take into account the inevitable variability in methods of measurement calculated in accordance with 12.7.3.1.

NOTE 1 ISO 3443-1 to -3 give guidance on tolerances for buildings and the implications of variabilities (including manufacturing, setting-out and erection deviations) on the fit between components.

Accuracy of construction shall be interpreted in relation to the expected deflections, cambers, presets, elastic movements and thermal expansion of components.

NOTE 2 EN 1993-1-4 gives values for the coefficient of thermal expansion for common stainless steels.

If significant movement of a structure is anticipated that could affect dimensional checking (e.g. for tension structures) an envelope of permissible positions shall be specified.

12.7.3.7 Action on nonconformity

Action on nonconformity shall be in accordance with 12.3. Corrections shall be carried out using methods that are in accordance with this European Standard.

If a steel structure is handed over with uncorrected nonconformities awaiting action these shall be listed.

12.7.4 Other acceptance tests

If components of a structure are to be erected to a specific load rather than position, detailed requirements, including tolerance range on the load shall be specified.

Annex A
(normative)

Additional information, list of options and requirements related to the execution classes

A.1 List of required additional information

This clause lists in Table A.1 the additional information that is required in the text of this European Standard as appropriate to fully define the requirements for execution of the work to be in accordance with this European Standard (i.e. where the wording “shall be specified” is used).

Table A.1 — Additional information

Clause	Additional information required
5 – Constituent products	
5.1	Properties of products not covered by listed standards
5.3.1	Grades, qualities and, if appropriate, coating weights and finishes for steel products
5.3.3	Additional requirements related to special restrictions on either surface imperfections or repair of surface defects by grinding in accordance with EN 10163, or with EN 10088 for stainless steel
5.3.3	Surface finish requirements for other product
5.3.4	Internal discontinuity quality class S1 of EN 10160 for EXC3 and EXC4
5.3.4	Additional requirement for special properties if relevant
5.4	Grades, grade suffixes and finishes for steel castings
5.6.3	Property classes of bolts and nuts, and surface finishes for structural bolting assemblies for non preloaded applications Mechanical properties for some bolting assemblies Full details for the use of insulation kits
5.6.4	Property classes of bolts and nuts and surface finishes for structural bolting assemblies for preloading
5.6.6	Chemical composition of weather resistant assemblies
5.6.11	Mechanical fastener type for use in stressed skin applications
5.6.12	Special fastener not standardised in CEN or ISO standards, as well as any tests necessary
5.8	Grouting materials to be used
5.9	Requirements for type and characteristics of expansion joints
5.10	Tensile strength grade and coating of wires Designation and class of strands Minimum breaking load and diameter of steel wire ropes and requirements related to corrosion protection

Clause	Additional information required
6 – Preparation and assembly	
6.2 d)	Areas where the marking method would not affect the fatigue life
6.2	Zones where identification marks are not permitted or shall not be visible after completion
6.5.4 b)	Minimum bending radii for stainless steels other than those to referred grades
6.5.4 c)	Protective membranes for cold formed thin gauge components
6.6.1	Special dimensions for movement joints
6.6.1	Nominal hole diameter for hot rivets
6.6.1	Dimensions of countersinking
6.7	Locations where sharp re-entrant corners are not permitted for thin gauge components and sheeting, with the minimum acceptable radii
6.9	Special requirements to connections for temporary components, including those related to fatigue
7 – Welding	
7.5.6	Areas where welding of temporary attachments is not permitted
7.5.6	Use of temporary attachments for EXC3 and EXC4
7.5.13	Dimensions of holes for slot and plug welds
7.5.14.1	Minimum visible width of arc spot welds
7.5.15	Requirements for other weld types
7.5.17	Requirements for grinding and dressing of the surface of completed welds
7.7.2	Surface finish of the weld zones on stainless steels
7.6	Any additional requirements for weld geometry and profile
7.7.3	Requirements for welding different stainless steels to each other or to other metallic materials
8 – Mechanical fastening	
8.2.2	Minimum diameter of fasteners for thin gauge components and sheeting Dimensions of bolts in connection utilising the shear capacity of the unthreaded shank
8.2.4	Dimensions and steel grade of plate washers to be used with long slotted or oversized holes Dimensions and steel grade of taper washers
8.4	Requirements related to contact surfaces in slip resistant connections for stainless steels
8.4	Area of contact surfaces in preloaded joints
8.8.4	Requirements for the side lap fasteners as structural fasteners
8.9	Requirements and any tests required for use of special fasteners and fastening methods
8.9	Requirements for use of hexagon injection bolts
9 – Erection	
9.4.1	Reference temperature for setting out and measuring the steelwork
9.5.5	Method of sealing the edges of a base plate if no grouting is needed

Clause	Additional information required
10 – **Surface treatment**	
10.1	Requirements to take account of the particular coating system to be applied
10.2	Preparation grade of surfaces or expected life of the corrosion protection together with the corrosivity category
10.3	If necessary, procedures to ensure that the surface of uncoated weather resistant steels is acceptable visually after weathering
10.3	Requirements for surface treatment of contact non-weather/weather resistant steels
10.6	Internal treatment system, if enclosed spaces are to be sealed by welding or provided with internal protective treatment
10.6	Method to be used for sealing the interface if mechanical fasteners penetrate the wall of sealed enclosed spaces
10.9	Method and extent of repairs after cutting or welding
10.10.2	Method, level and extent of cleaning of stainless steels
11 – **Geometrical tolerances**	
11.1	Additional information related to special tolerances if these tolerances are specified
11.3.1	The system of functional tolerances to be used
12 – **Inspection, testing and corrections**	
12.3	Location and frequency of measurements for geometrical dimensions of components
12.5.1	Requirements for checking the installation of an insulation system
12.5.2.1	Requirements for inspection and testing of preloaded bolts used for stainless steels connections
12.5.5.1	Requirements for inspection of connections using special fasteners or special fastening methods
12.7.1	Requirements for inspection of trial erection
12.7.3.4	Location and frequency of measurements for the survey of geometrical position of connection nodes
12.7.4	Tolerance range on the load, if components of a structure are to be erected to a specific load
Annex F – Corrosion protection	
F.1.2	Performance specification for corrosion protection
F.1.3	Prescriptive requirements for corrosion protection
F.4	Extent of surfaces that are affected by the preloaded bolts in non slip resistant connections
F.6.3	Requirements for procedure qualification of the dipping process if hot dip galvanizing of cold-formed components after manufacture is specified
F.6.3	Requirements for the inspection, checking or qualification of the preparation to be carried out before subsequent overcoating, for galvanized components

A.2 List of options

This Annex lists the items which may be specified in the execution specification to define requirements for the execution of the work where options are given in this European Standard.

Table A.2 — List of options

Clause	Option(s) to be specified
4 – Specifications and documentation	
4.2.2	If a quality plan for execution of the works is required
5 – Constituent products	
5.2	If traceability for each product is specified
5.3.1	If structural steel products other than those listed in Tables 2, 3 and 4 are to be used
5.3.2	If other thickness tolerances for structural steel plates are spec ifid
5.3.2	If thickness class other than class A is to be used for other structural and stainless steel products
5.3.3	If more stringent surface conditions are required for plates in EXC3 and EXC4
5.3.3 b)	If discontinuities such as cracks, shell and seams shall be repaired
5.3.3	If decorative or specialist surface finishes are specified
5.3.4	If areas close to bearing diaphragms or stiffeners are to be checked for the existence of internal discontinuities
5.5	If other options than those in Table 6 shall be used
5.6.3	If fasteners according to EN ISO 898-1 and EN 20898-2 can be used to join stainless steels according to EN 10088
5.6.4	If stainless steel bolts can be used in preloaded applications
5.6.7	If reinforcing steels may be used for foundation bolts together with the steel grade
5.6.8	If locking devices are required
5.6.8	If other products than those in the referred standards are to be used
6 – Preparation and assembly	
6.2	If other requirements apply to hard stamped numbers, punched or drilled marks
6.2	If soft or low stress stamps may be used
6.2	If soft or low stress stamps may not be used for stainless steels
6.4.4	If hardness of free edge surfaces is specified for carbon steels
6.4.4	If other requirements are specified for the check of the capability of cutting processes
6.5.4 b)	Other minimum bending radii for stainless steels to referred grades
6.5.4 d)	Other conditions for circular tubes bending by cold forming
6.6.1 Table 11 a)	Other nominal clearance for normal round holes for applications such as towers and masts
6.6.2	Other tolerances on hole diameter
6.6.3	If holes formed by punching shall be reamed for EXC1 and EXC2
6.6.3	Other specification for long slotted holes

Clause	Option(s) to be specified
6.8	If full contact bearing surfaces are specified
6.10	If, and to what extent, trial assembly is to be used
7 – **Welding**	
7.3	If use of other welding processes is explicitly allowed
7.4.1.1	If special deposition conditions for tack welds are required
74.1.2 b) 1)	If impact tests are required
7.4.1.4	If welding production tests are required
7.5.4	Other specification than in Annex E for assembly of hollow section components to be welded
7.5.6	If cutting and chipping are permitted for EXC3 and EXC4
7.5.8.2	If end returns on fillet welds for thin gauge components shall not be completed
7.5.9.1	If run-on/run-off pieces are required for EXC2
7.5.9.1	If a flush surface is required
7.5.9.2	If permanent steel backing material shall not be used for single side welds
7.5.9.2	If flush grinding of single-sided butt welds in joints between hollow sections executed without backing is permitted
7.5.13	If plug welds performed without previous slot welding are permitted
7.5.14.1	If weld washers are accepted for stainless steels
7.7.1	Other methods than contact pyrometers to measure temperature
7.7.2	If the coloured oxide films formed during welding shall be removed for stainless steels
7.7.2	If slag associated with welding may not be removed
7.7.2	If copper backing may be used for stainless steels
8 – **Mechanical fastening**	
8.2.1	If, in addition to tightening measures or other means are to be used to secure the nuts
8.2.1	If bolts and nuts may be welded
8.2.2	If nominal fastener diameter may be less than M12 for structural bolting
8.2.4	If washers are required for non-preloaded bolt connections
8.3	If full contact bearing is specified (see 6.8)
8.5.1	Other nominal minimum preloading force value together with the relevant bolt assemblies, tightening method, thigtening parameters and inspection requirements
8.5.1	If there are restrictions on use of any of the tightening methods given in Table 20
8.5.1	If calibration to Annex H for the torque method is permitted
8.5.1	If measures shall be taken to offset possible subsequent loss of preloading force
8.5.4 a)	If another value than $Mr,_1 = 0{,}13\ d\ F_{p,C}$ is to be used
8.5.4	If other values than those given in Table 21 are specified
8.5.5	If the first step of HRC bolts is to be repeated
8.6	If the length of the threaded portion of the shank of the fit bolt (including thread run out) included in the bearing length may exceed 1/3 of the thickness of the plate
8.7.2	If a flush surface of countersunk rivets is specified
8.7.3	If outer faces of plies shall be free of indentation by the riveting machine
8.8.2	If the fasteners for thin gauge components may be located elsewhere than in the valley of the

	corrugation
Clause	**Option(s) to be specified**
9 – **Erection**	
9.5.3	If compensation for settlement of supports is not acceptable
9.5.4	If levelling nuts on the foundation bolts under the base plate shall be removed
9.5.4	If packings subsequently to be grouted, may be placed so that the grout does not totally encloses them
9.5.4	If packings for bridges may be left in position
9.5.5	If treatment of steelwork, bearings and concrete surfaces is required before grouting
9.6.5.2	If it is required that bracings in tall buildings are to be de-stressed as erection progresses
9.6.5.3	If material of shims may be different from flat steel
10 – **Surface treatment**	
10.1	If corrosion protection is required
10.2	If there are requirements for surface treatment of stainless steels
10.5	If enclosed spaces shall be sealed after galvanizing and, if so, with what
10.6	If weld imperfections permitted under the welding specification require sealing by application of suitable filler material
10.6	If sealing welds require further inspection after visual inspection
10.7	If there are specific requirements for coating surfaces in contact with concrete
10.8	If faying surfaces and surfaces beneath washers may not be treated
10.8	If bolted connections including the perimeter around such connections may not be treated with the full corrosion protection system specified for the remainder of the steelwork.
10.9	if repair, or additional protective treatment, is required to cut edges and adjacent surfaces after cutting
11 – **Geometrical tolerances**	
11.2.3.5	If shims may not be used to reduce the gap of bolt splices in full contact bearing
11.3.3	If specified alternative criteria may be applied
12 – **Inspection, testing and corrections**	
12.2.1	If there are requirements for specific testing of constituent products
12.3	Other methods for repairing damage resulting in local dents in the surface of hollow sections
12.4.2.2	If additional NDT are required for EXC1
12.4.2.2	If specific joints are identified for inspection together with the extent and method of testing
12.4.4	If production tests are required for EXC3 and EXC4
12.5.2.3	Other inspection method than sequential sampling plan in Annex M
12.5.2.3	If checking of over-tightening is required
12.7.3.1	If there is a requirement to record dimensional checks at acceptance of the structure for EXC3 and EXC4
12.7.3.4	Other extent of measurements for the survey of geometrical position of connection nodes
12.7.3.4	Conditions of measurements other than under the self weight of steelwork

Clause	Option(s) to be specified
Annex F – Corrosion protection	
F.2.2	Other requirements than EN ISO 8501 and EN ISO 1461 for surface preparation of carbon steels
F.5	If the lower embedded part of foundation bolts shall not be left untreated
F.7.3	If reference areas are not specified for corrosion protection systems in Corrosivity Categories C3 to C5 and Im1 to Im3
F.7.4	If galvanized components are not subjected to post-galvanizing inspection (LMAC)

A.3 Requirements related to the execution classes

This clause lists requirements specific to each of the execution classes referenced in this European Standard. “Nr” in the table means: No specific requirement in the text.

Items identified in bold letters in Table A.3 relate to the general system of control of execution and are amenable to a common choice of execution class across the whole of the works (or a phase of the works). The other items generally demand the selection of the appropriate execution class on a component–by-component or a connection detail-by-detail basis.

Table A.3 — Requirements to each execution class

Clauses	EXC1	EXC2	EXC3	EXC4
4 – Specifications and documentation				
4.2 Constructor’s documentation				
4.2.1 Quality documentation	Nr (No requirement)	Yes	Yes	Yes
5 – Constituent products				
5.2 Identification, inspection documents and traceability				
Inspection documents	See Table 1	See Table 1	See Table 1	See Table 1
Traceability	Nr (No requirement)	Yes (partial)	Yes (full)	Yes (full)
Marking	Nr	Yes	Yes	Yes
5.3 Structural steels products				
5.3.2 Thickness tolerances	Class A	Class A	Class A	Class B
5.3.3 Surface conditions	Flat - Class A2 Long – Class C1	Flat - Class A2 Long – Class C1	More stringent conditions if specified	More stringent conditions if specified
5.3.4 Special properties	Nr	Nr	Internal discontinuity quality class S1 for welded cruciform joints	Internal discontinuity quality class S1 for welded cruciform joints
6 – Preparation and assembly				
6.2 Identification	Nr	Nr	Finished components / Inspection certificates	Finished components / Inspection certificates

Clauses	EXC1	EXC2	EXC3	EXC4
6.4 Cutting				
6.4.3 Thermal cutting	Free from significant irregularities Hardness according Table 10, if specified	EN ISO 9013 u = range 4 Rz5 = range 4 Hardness according Table 10, if specified	EN ISO 9013 u = range 4 Rz5 = range 4 Hardness according Table 10, if specified	EN ISO 9013 u = range 3 Rz5 = range 3 Hardness according Table 10, if specified
6.5 Shaping				
6.5.3 Flame straightening	Nr	Nr	Suitable procedure to be developed	Suitable procedure to be developed
6.6 Holing				
6.6.3 Execution of holing	Punching	Punching	Punching + reaming	Punching + reaming
6.7 Cut-outs	Nr	Min. radius 5 mm	Min. radius 5 mm	Min. radius 10 mm Punching not permitted
6.9 Assembly	Drifting: Elongation Functional tolerance Class 1	Drifting: Elongation Functional tolerance Class 1	Drifting: Elongation Functional tolerance Class 2	Drifting: Elongation Functional tolerance Class 2
7 – Welding				
7.1 General	EN ISO 3834-4	EN ISO 3834-3	EN ISO 3834-2	EN ISO 3834-2
7.4 Qualification of welding procedures and welding personnel				
7.4.1 Qualification of welding procedures	Nr	See Table 12 and Table 13	See Table 12 and Table 13	See Table 12 and Table 13
7.4.2 Qualification of welders and operators	Welders: EN 287-1 Operators: EN 1418	Welders: EN 287-1 Operators: EN 1418	Welders: EN 287-1 Operators: EN 1418	Welders: EN 287-1 Operators: EN 1418
7.4.3 Welding coordination	Nr	Technical knowledge according Tables 14 or 15	Technical knowledge according Tables 14 or 15	Technical knowledge according Tables 14 or 15
7.5.1 Joint preparation	Nr	Nr	Prefabrication primers not allowed	Prefabrication primers not allowed
7.5.6 Temporary attachments	Nr	Nr	Use to be specified Cutting and chipping not permitted	Use to be specified Cutting and chipping not permitted
7.5.7 Tack welds	Nr	Qualified welding procedure	Qualified welding procedure	Qualified welding procedure

Clauses	EXC1	EXC2	EXC3	EXC4
7.5.9 Butt welds 7.5.9.1 General 7.5.9.2 Single side welds	Nr	Run on/run off pieces if specified	Run on/run off pieces Permanent backing continuous	Run on/run off pieces Permanent backing continuous
7.5.17 Execution of welding			Removal of spatter	Removal of spatter
7.6 Acceptance criteria	EN ISO 5817 Quality level D if specified	EN ISO 5817 Quality level C generally	EN ISO 5817 Quality level B	EN ISO 5817 Quality level B +
9 – Erection				
9.6 Erection and work at site				
9.6.3 Handling and storage on site	Nr	Documented restoration procedure	Documented restoration procedure	Documented restoration procedure
9.6.5.3 Fit up and alignment	Nr	Nr	Securing shims by welding subject to requirements of 7	Securing shims by welding subject to requirements of 7
12 – Inspection, testing and repair				
12.4.2 Inspection after welding				
12.4.2.2 Scope of inspection **12.4.2.5 Correction of welds**	Visual inspection No WPQ required	NDT: See Table 24 According to WPQ	NDT: See Table 24 According to WPQ	NDT: See Table 24 According to WPQ
12.4.4 Production tests	Nr	Nr	If specified	If specified
12.5.2 Inspection of preloaded bolts connections	Nr	as follows	as follows	as follows

12.5.2.2 **Before tightening** **12.5.2.3** **During and after tightening** **12.5.2.4** **Torque method** **12.5.2.5** **Combined method**		Checking the tightening procedure 2nd tightening step Sequential type A Assembly lot location 2nd tightening step Inspection of marking 2nd tightening step	Checking the tightening procedure 1st tightening step 2nd tightening step Sequential type A Assembly lot location Checking tightening procedure (each bolt lot) 2nd tightening step 1st tightening step Inspection of marking 2nd tightening step	Checking the tightening procedure 1st pretightening step 2nd tightening step Sequential type B Assembly lot location Checking tightening procedure (each bolt lot) 2nd tightening step 1st tightening step Inspection of marking 2nd tightening step
12.5.3.1 **Inspection, testing and repair of hot rivets**	Nr	Ring test Sequential type A	Ring test Sequential type A	Ring test Sequential type B
12.7.3.1 **Survey of the geometrical position of connection nodes**	Nr	Nr	Record of the survey	Record of the survey

Annex B
(informative)

Guidance for the determination of execution classes

B.1 Introduction

This annex provides guidance for the choice of execution classes with respect to those execution factors that affect the overall reliability of the completed works and which is a prerequisite for the application of the various clauses in this European Standard.

NOTE The recommended procedure for determination and the use of execution class according to EN 1090-2 takes into account the fact that the design will be carried out in accordance with EN 1993 for steel structures or EN 1994 for the steel parts of composite structures to achieve consistency between the assumptions made in the structural design and the requirements for execution of the work. The determination of execution class is done in the design phase where specifics for design and execution of the structure are evaluated, and the information on execution requirements are given in the execution specification. The guidelines in this annex may be wholly or partially superseded by future guidelines added to EN 1993.

B.2 Governing factors for choice of execution class

B.2.1 Consequence classes

EN 1990:2002 gives in its Annex B guidelines for the choice of consequence class for the purpose of reliability differentiation. Consequence classes for structural components are divided in three levels denoted CCi (i = 1, 2 or 3).

NOTE Annex B in EN 1990:2002 is informative. Consequently the national annex to EN 1990 may give provisions for the application of this annex.

EN 1991-1-7 gives examples of categorisation of building type and occupancy according to consequence classes that assist with the implementation of Annex B of EN 1990:2002.

A structure, or a part of it, can contain components with different consequence classes.

B.2.2 Hazards connected with execution and use of the structure

B.2.2.1 General

Such hazards may arise from the complexity of the work execution and from uncertainty in the exposure and actions on the structure that can expose flaws in the structure during use.

Potential hazards are in particular connected with:

— service factors arising from the actions to which the structure and its parts are likely to be exposed to during erection and use and the stress levels in the components in relation to their resistance;

— production factors arising from the complexity of the execution of the structure and its components, e.g. application of particular techniques, procedures or controls.

To account for this differentiation in hazards service categories and production categories are introduced.

B.2.2.2 Hazards connected with the use of the structure

The service category may be determined on the basis of Table B.1.

Table B.1 — Suggested criteria for service categories

Categories	Criteria
SC1	• Structures and components designed for quasi static actions only (Example: Buildings) • Structures and components with their connections designed for seismic actions in regions with low seismic activity and in DCL* • Structures and components designed for fatigue actions from cranes (class S_0)**
SC2	• Structures and components designed for fatigue actions according to EN 1993. (Examples: Road and railway bridges, cranes (class S_1 to S_9)**, structures susceptible to vibrations induced by wind, crowd or rotating machinery) • Structures and components with their connections designed for seismic actions in regions with medium or high seismic activity and in DCM* and DCH*
* DCL, DCM, DCH: ductility classes according to EN 1998-1 ** For classification of fatigue actions from cranes, see EN 1991-3 and EN 13001-1	

A structure or part of a structure can contain components or structural details that belong to different service categories.

B.2.2.3 Hazards connected with execution of the structure

The production category may be determined on the basis of Table B.2.

Table B.2 — Suggested criteria for production categories

Categories	Criteria
PC1	• Non welded components manufactured from any steel grade products • Welded components manufactured from steel grade products below S355
PC2	• Welded components manufactured from steel grade products from S355 and above • Components essential for structural integrity that are assembled by welding on construction site • Components with hot forming manufacturing or receiving thermic treatment during manufacturing • Components of CHS lattice girders requiring end profile cuts

A structure or part of a structure may contain components or structural details that belong to different production categories.

B.3 Determination of execution classes

The recommended procedure for determination of execution class is in three steps:

a) selection of a consequence class, expressed in terms of predictable consequences either human, economical or environmental of a failure or collapse of a component (see EN 1990);

b) selection of a service category and a production category (see Table B.1 and B.2);

c) determination of the execution class from the results of the operations a) and b) according to Table B.3.

NOTE The determination of the execution class should be taken by the designer and the owner of the construction works in cooperation, taking national provisions into account. In this decision process the project manager and the constructor should be consulted as appropriate following any national provisions in the place of use for the structure.

Table B.3 gives the recommended matrix for selection of execution class from the determined consequence class and the selected production and service category.

Table B.3 — Recommended matrix for determination of execution classes

Consequence classes		**CC1**		**CC2**		**CC3**	
Service categories		**SC1**	**SC2**	**SC1**	**SC2**	**SC1**	**SC2**
Production categories	**PC1**	EXC1	EXC2	EXC2	EXC3	EXC3 [a]	EXC3 [a]
	PC2	**EXC2**	**EXC2**	**EXC2**	**EXC3**	**EXC3** [a]	**EXC4**
[a] EXC4 should be applied to special structures or structures with extreme consequences of a structural failure as required by national provisions.							

The execution class determines the requirements for the various activities of the execution given in this European Standard. The requirements are summarised in Annex A.3.

Annex C
(informative)

Check-list for the content of a quality plan

C.1 Introduction

In accordance with 4.2.2 this annex gives the list of recommended items to be included in a project-specific quality plan for the execution of a steel structure.

C.2 Content

C.2.1 Management

Definition of the particular steel structure and its location with relation to the project.

Project management organisation plan giving names key personnel, their function and responsibilities during the project, the chain of command and lines of communication.

Arrangements for planning and coordination with other parties throughout the project and for monitoring of performance and progress.

Identification of functions delegated to subcontractors and others not in-house.

Identification and proof of competence of qualified personnel to be employed on the project, including welding coordination personnel, inspection personnel, welders and welding operators.

Arrangements for controlling variations, changes and concessions that take place during the project.

C.2.2 Specification review

Requirement to review the specified project requirements to identify the implications including the choices of execution classes that would require additional or unusual measures beyond those assured by the company's quality management system.

Additional quality management procedures necessitated by the review of the specified project requirements.

C.2.3 Documentation

C.2.3.1 General

Procedures to manage all received and issued execution documentation, including identification of the current revision status and prevention of the use of invalid or obsolete documents in-house or by subcontractors.

C.2.3.2 Documentation prior to execution

Procedures for providing documentation prior to execution, including:

a) certificates for constituent products including consumables;

b) weld procedure specifications and qualification records;

c) method statements including those for erection and preloading fasteners;

d) design calculations for temporary works necessitated by the erection methods;

e) arrangements for scope and timing of second or third party approval or acceptance of documentation prior to execution.

C.2.3.3 Execution records

Procedures for providing execution records, including:

a) constituent products traced to completed components;

b) inspection and test reports and action taken to deal with nonconformities, concerning:

1) Preparation of joint faces prior to welding,

2) Welding and completed weldments,

3) Geometrical tolerances of manufactured components,

4) Surface preparation and treatment,

5) Calibration of equipment including those used for control of preloading of fasteners;

c) pre-erection survey results leading to acceptance that the site is suitable for erection to commence;

d) delivery schedules for components delivered to site identified to location with the completed structure;

e) dimensional surveys of the structure and action taken to deal with nonconformities;

f) certificates for completion of erection and handover.

C.2.3.4 Documentary records

Arrangements for making documentary records available for inspection, and for retaining them for a minimum period of five years, or longer if required by the project.

C.2.4 Inspection and testing procedures

Identification of the mandatory tests and inspections required by the standard and those provided in the constructor's quality system that are necessary for the execution of the project, including:

a) the scope of inspection;

b) acceptance criteria;

c) actions for dealing with nonconformities, corrections and concessions;

d) release/rejection procedures.

Project-specific requirements for inspection and testing, including requirements that particular tests or inspections are to be witnessed, or points where a nominated third party is to carry out an inspection.

Identification of hold points associated with second or third party witnessing, approval or acceptance of test or inspection results.

Annex D
(normative)

Geometrical tolerances

D.1 Essential tolerances

Permitted deviations for essential tolerances are tabulated in:

D.1.1: Essential manufacturing tolerances – Welded profiles

D.1.2: Essential manufacturing tolerances – Press braked cold formed profiles

D.1.3: Essential manufacturing tolerances – Flanges of welded profiles

D.1.4: Essential manufacturing tolerances – Flanges of welded box sections

D.1.5: Essential manufacturing tolerances – Web stiffeners of profiles or box sections

D.1.6: Essential manufacturing tolerances – Stiffened plating

D.1.7: Essential manufacturing tolerances – Cold formed profiled sheets

D.1.8: Essential manufacturing tolerances – Fastener holes, notches and cut edges

D.1.9: Essential manufacturing tolerances – Cylindrical and conical shells

D.1.10: Essential manufacturing tolerances – Lattice components

D.1.11: Essential erection tolerances – Single storey columns

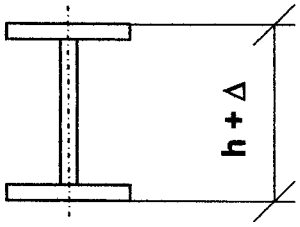
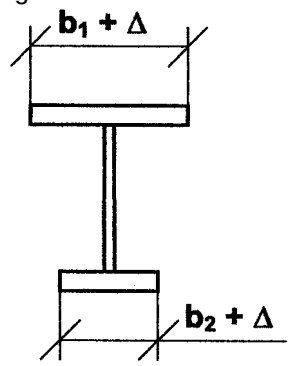
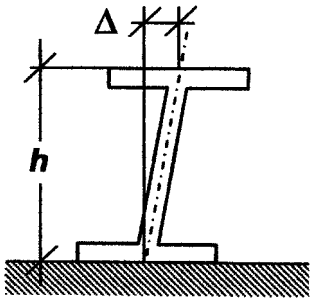
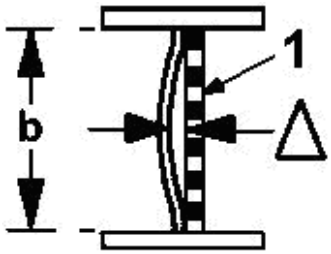
D.1.12: Essential erection tolerances – Multi-storey columns

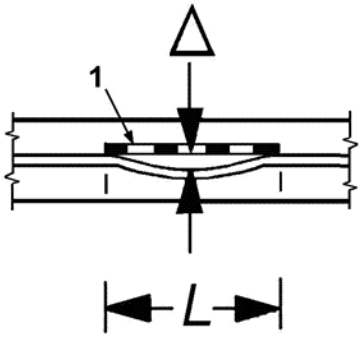
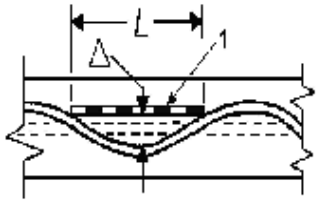
D.1.13: Essential erection tolerances – Full contact end bearing

D.1.14: Essential erection tolerances – Towers and masts

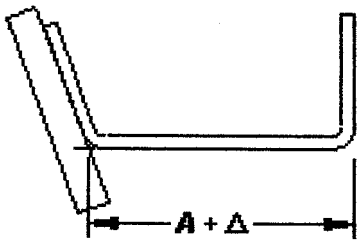
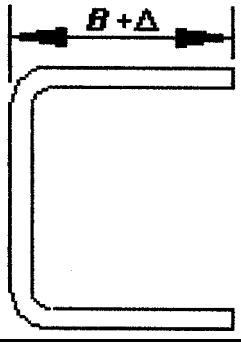
D.1.15: Essential erection tolerances – Beams subject to bending and components subject to compression

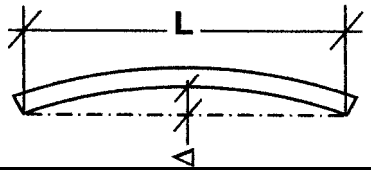
D.1.1 Essential manufacturing tolerances – Welded profiles

No	Criterion	Parameter	Permitted deviation Δ
1	Depth: 	Overall depth *h*:	Δ = - *h* /50 (no positive value given)
2	Flange width: 	Width $b = b_1$ or b_2:	Δ = - *b* /100 (no positive value given)
3	Squareness at bearings: 	Verticality of web at supports, for components without bearing stiffeners:	Δ = ± *h* /200 but Δ ≥ t_w (t_w = web thickness)
4	Plate curvature: 	Deviation Δ over plate height *b*:	Δ = ± *b* /100 but Δ ≥ *t* (*t* = plate thickness)

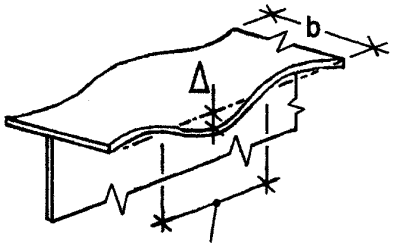
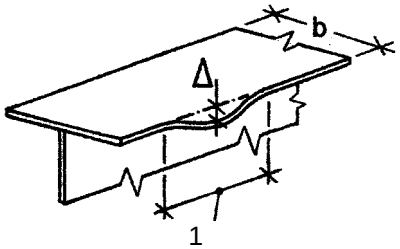
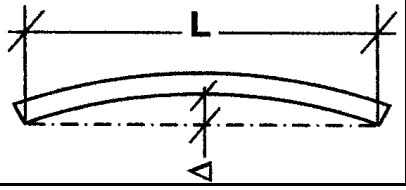
5	Web distortion:  	Deviation Δ on gauge length L equal to plate length b:	$\Delta = \pm b/100$ but $\lvert\Delta\rvert \geq t$ (t = plate thickness)
6	Web undulation:  	Deviation Δ on gauge length L equal to plate length b:	$\Delta = \pm b/100$ but $\lvert\Delta\rvert \geq t$ (t = plate thickness)
Key 1 gauge length NOTE Notations such as $\lvert\Delta\rvert = d/100$ but $\lvert\Delta\rvert \geq t$ mean that the *larger* of the two values is permitted.			

D.1.2 Essential manufacturing tolerances – Press braked cold formed profiles

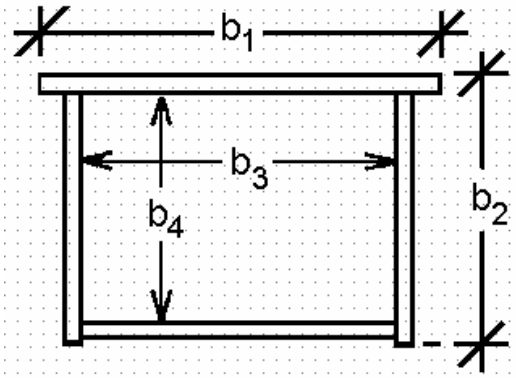
No	Criterion	Parameter	Permitted deviation Δ
1	Internal element width:  	Width A between bends:	$-\Delta = A/50$ (no positive value given)
2	Outstand element width:  	Width B between a bend and a free edge:	$-\Delta = B/80$ (no positive value given)

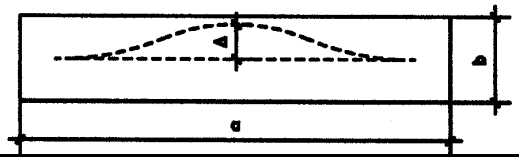
3	Straightness for components to be used unrestrained: 	Deviation Δ from straightness	Δ = ± *L* / 750

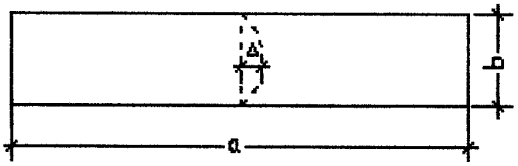
D.1.3 Essential manufacturing tolerances – Flanges of welded profiles

No	Criterion	Parameter	Permitted deviation Δ
1	Flange distortion of I section: 	Distortion Δ on gauge length *L* where *L* = flange width *b*	Δ = ± *b* / 100
2	Flange undulation of I section: 	Distortion Δ on gauge length *L* where *L* = flange width *b*	Δ = ± *b* / 100
3	Straightness for components to be used unrestrained: 	Deviation Δ from straightness	Δ = ± *L* / 750
Key 1 gauge length			

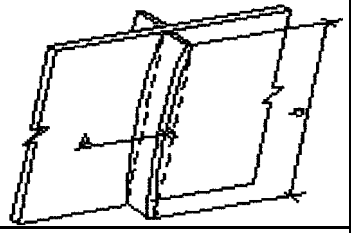
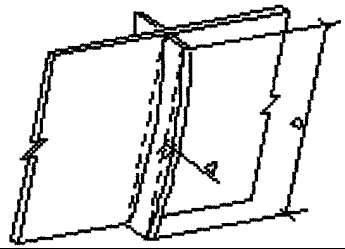
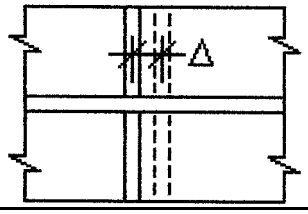
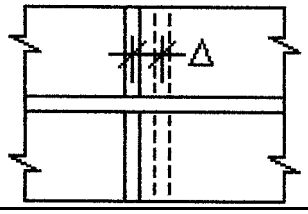
D.1.4 Essential manufacturing tolerances – Flanges of welded box sections

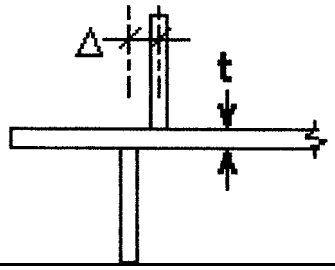
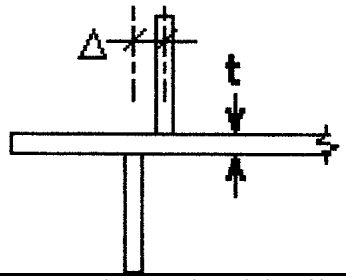
No	Criterion	Parameter	Permitted deviation Δ
1	Section dimensions: 	Internal or external dimensions: where: $b = b_1$, b_2, b_3 or b_4	$- \Delta = b/100$ (no positive value given)

2	Out of plane imperfections of plate panels between webs or stiffeners, general case:
	 
		Distortion Δ perpendicular to the plane of the plate:
		if $a \leq 2b$:
		if $a > 2b$:
			$\Delta = \pm a/250$
			$\Delta = \pm b/125$

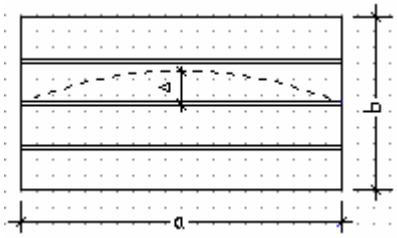
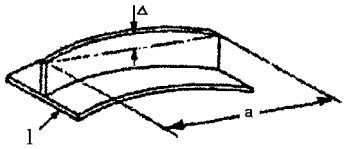
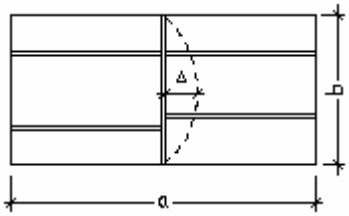
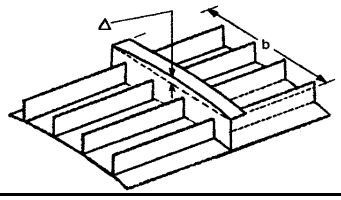
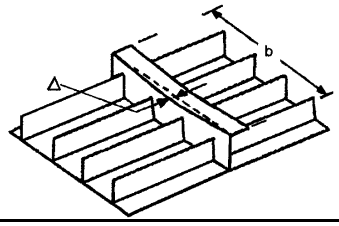
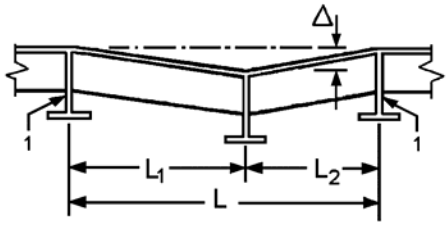
3	Out of plane imperfections of plate panels between webs or stiffeners (special case with compression in the transverse direction – the general case applies unless this special case is specified):
	 
		Distortion Δ perpendicular to the plane of the plate:
		if $b \leq 2a$:
		if $b > 2a$:
			$\Delta = \pm b/250$
			$\Delta = \pm a/125$

D.1.5 Essential manufacturing tolerances – Web stiffeners of profiles or box sections

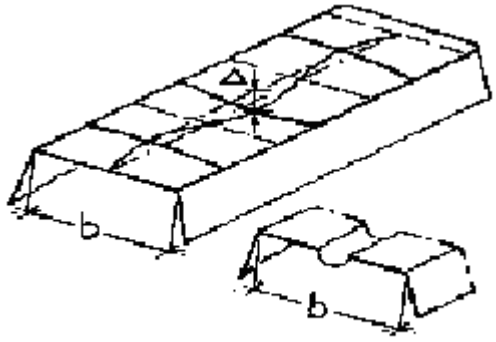
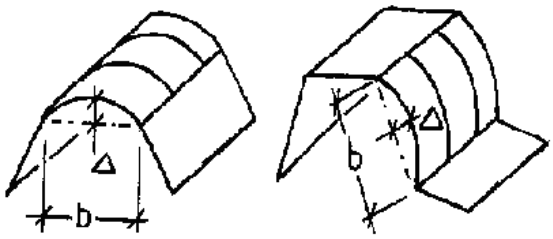
No	Criterion	Parameter	Permitted deviation Δ
1	In plane straightness: 	Deviation Δ from straightness in the plane of the web:	$\Delta = \pm b/250$ but $\lvert\Delta\rvert \geq 4$ mm
2	Out of plane straightness: 	Deviation Δ from straightness normal to the plane of the web:	$\Delta = \pm b/500$ but $\lvert\Delta\rvert \geq 4$ mm
3	Location of web stiffeners: 	Distance from intended location:	$\Delta = \pm 5$ mm
4	Location of web stiffeners at supports: 	Distance from intended location:	$\Delta = \pm 3$ mm

5	Eccentricity of web stiffeners:  	Eccentricity between a pair of stiffeners:	$\Delta = \pm t_w/2$
6	Eccentricity of web stiffeners at supports:  	Eccentricity between a pair of stiffeners:	$\Delta = \pm t_w/3$
NOTE Notations such as $\lvert\Delta\rvert = d/100$ but $\lvert\Delta\rvert \geq 5$ mm mean that the *larger* of the two values is permitted.			

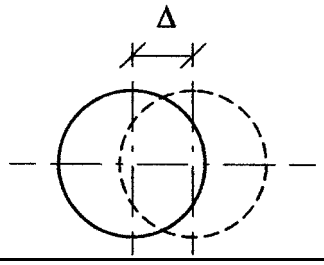
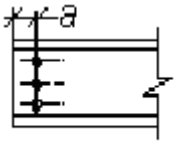
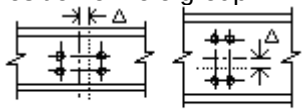
D.1.6 Essential manufacturing tolerances – Stiffened plating

No	Criterion	Parameter	Permitted deviation *Δ*
1	Straightness of stiffeners: Longitudinal stiffeners in longitudinally stiffened plating:  **Key** 1 plate	Deviation *Δ* perpendicular to the plate: 	Δ = ± *a*/400
2		Deviation *Δ* parallel to the plate: 	Δ = ± *b*/400
3	Straightness of stiffeners: Transverse stiffeners in transversely and longitudinally stiffened plating: 	Deviation *Δ* perpendicular to the plate: 	Smaller of: Δ = ± *a*/400 or Δ = ± *b*/400
4		Deviation *Δ* parallel to the plate: 	Δ = ± *b*/400
5	Levels of cross frames in stiffened plating: **Key** 1 cross member	Level relative to the adjacent cross frames: 	Δ = ± *L* / 400

D.1.7 Essential manufacturing tolerances – Cold formed profiled sheets

No	Criterion	Parameter	Permitted deviation Δ
1	Flatness of unstiffened or stiffened flange or web: 	Deviation Δ from flatness of nominally flat element	$\Delta \leq \pm b/50$
2	Curvature of web or flange: 	Deviation Δ from intended shape of web or flange over curve width *b*	$\Delta \leq \pm b/50$

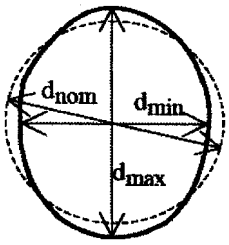
D.1.8 Essential manufacturing tolerances – Fastener holes, notches and cut edges

No	Criterion	Parameter	Permitted deviation Δ
1	Position of holes for fasteners: 	Deviation Δ of centreline of an individual hole from its intended position within a group of holes:	Δ = ± 2 mm
2	Position of holes for fasteners: 	Deviation Δ in distance *a* between an individual hole and a cut end:	- Δ = 0 (no positive value given)
3	Position of hole group: 	Deviation Δ of a hole group from its intended position:	Δ = ± 2 mm

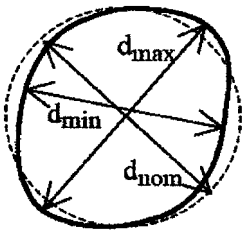
D.1.9 Essential manufacturing tolerances – Cylindrical and conical shells

No 1 — Criteria and details

Out-of-roundness:



a) flattening



b) unsymmetrical

Difference between the maximum and minimum values of the measured internal diameter, relative to the nominal internal diameter:

$$\Delta = \frac{(d_{max} - d_{min})}{d_{nom}}$$

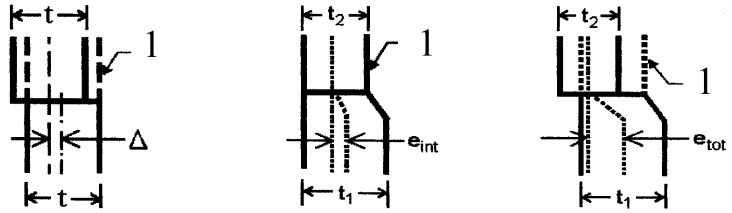
Tolerances			
	Permitted deviation Δ		
Diameter	$d \le 0{,}50$ m	0,50 m < d < 1,25 m	$d \ge 1{,}25$ m
Class A	$\Delta = \pm 0{,}014$	$\Delta = \pm [0{,}007 + 0{,}009\ 3(1{,}25 - d)]$	$\Delta = \pm 0{,}007$
Class B	$\Delta = \pm 0{,}020$	$\Delta = \pm [0{,}010 + 0{,}013\ 3(1{,}25 - d)]$	$\Delta = \pm 0{,}010$
Class C	$\Delta = \pm 0{,}030$	$\Delta = \pm [0{,}015 + 0{,}020\ 0(1{,}25 - d)]$	$\Delta = \pm 0{,}015$

NOTE d is the nominal internal diameter d_{nom} in metres.

No 2 — Misalignment:

Non-intended eccentricity of plates at a horizontal joint.
At a change of plate thickness, the intentional part of the eccentricity is not included.

Tolerances	
Class	Permitted deviation Δ
Class A	$\Delta = \pm 0{,}14t$ but $\lvert\Delta\rvert \le 2$ mm
Class B	$\Delta = \pm 0{,}20t$ but $\lvert\Delta\rvert \le 3$ mm
Class C	$\Delta = \pm 0{,}30t$ but $\lvert\Delta\rvert \le 4$ mm



At a change of plate thickness:

$t = (t_1 + t_2)/2$

$\Delta = e_{tot} - e_{int}$

where

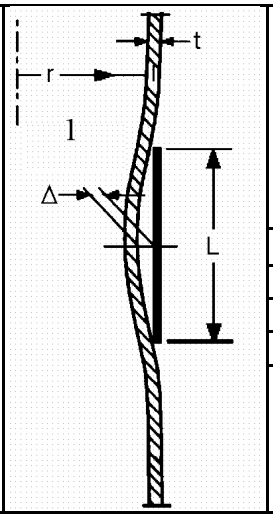
t_1 is the larger thickness;

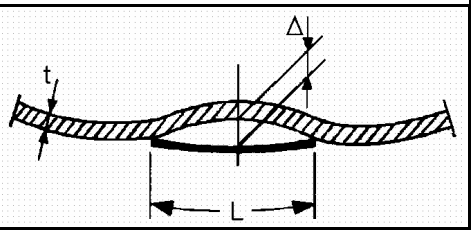
t_2 is the smaller thickness.

Key
1 intended joint geometry

No 3 — Dents (Dimples):

a) Meridionally:
$L = 4\ (rt)^{0,5}$
b) Circumferentially (gauge radius = r):
$L = 4\ (rt)^{0,5}$
$L = 2{,}3\ (h^2rt)^{0,25}$ but $L \le r$
where h is the axial length of the shell segment
c) Additionally, across welds:
$L = 25t$ but $L \le 500$ mm
NOTE At a change of thickness: $t = t_2$



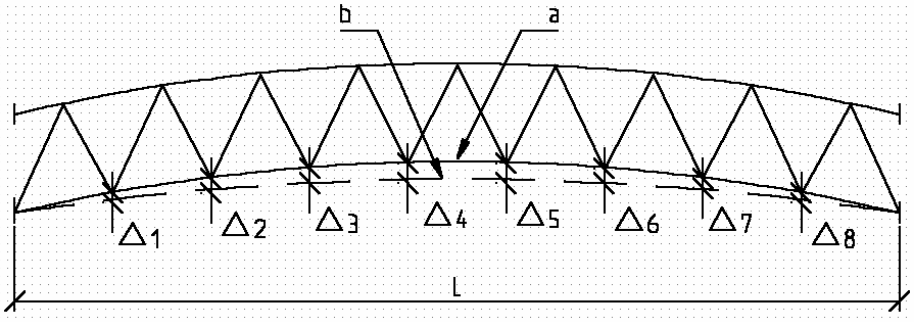


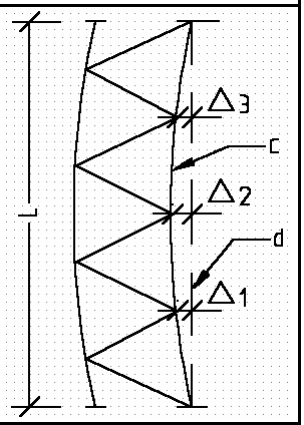
Tolerances	
Class	Permitted deviation Δ
Class A	$\Delta = \pm 0{,}006L$
Class B	$\Delta = \pm 0{,}010L$
Class C	$\Delta = \pm 0{,}016L$

Key
1 inward

NOTE With reference to the manufacturing tolerance quality classes in EN 1993-4-1, Class A = Excellent, Class B = High and Class C = Normal.

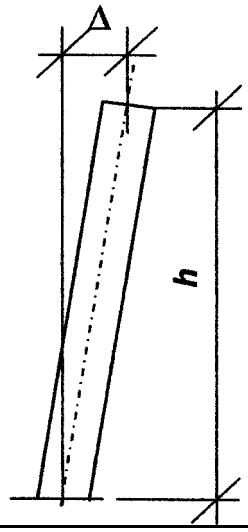
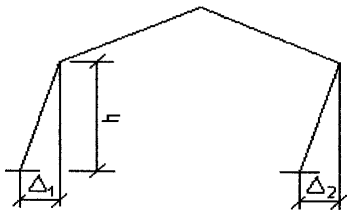
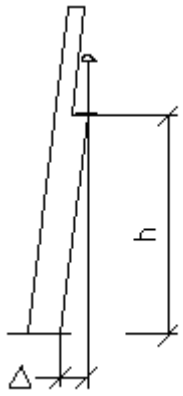
D.1.10 Essential manufacturing tolerances – Lattice components

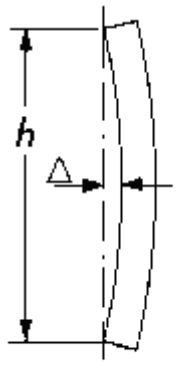
<table>
<tr><th>No</th><th>Criterion</th><th>Parameter</th><th>Permitted deviation Δ</th></tr>
<tr><td rowspan="2">1</td><td>Straightness and camber:
 



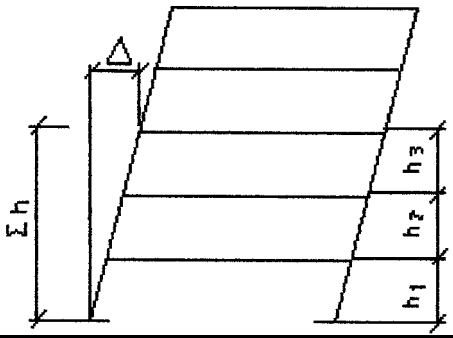
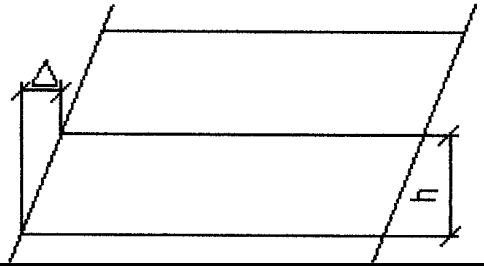
NOTE Deviations measured after welding, with the component lying flat on its side.</td><td></td><td></td></tr>
<tr><td>Key
a actual camber
b intended camber
c actual line
d intended line</td><td>Deviation at each panel point, relative to a straight line - or to the intended camber or curvature.</td><td>Δ = ± L/500
But |Δ| ≥ 12 mm</td></tr>
<tr><td>2</td><td>Straightness of bracing components:</td><td>Deviation of bracing from straightness:</td><td>Δ = ± L/750
but |Δ| ≥ 6 mm</td></tr>
<tr><td colspan="4">NOTE Notation such Δ = ± L / 500 but |Δ| ≥ 6 mm means that the larger of the two values is permitted.</td></tr>
</table>

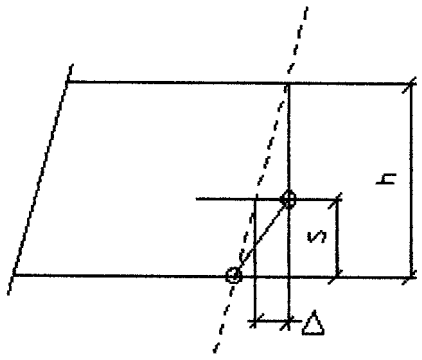
D.1.11 Essential erection tolerances – Single storey columns

No	Criterion	Parameter	Permitted deviation Δ
1	Inclination of single-storey columns generally: 	Overall inclination in storey height *h*:	$\Delta = \pm h/300$
2	Inclination of single storey columns in portal frame buildings: 	Mean inclination of all the columns in the same frame: [For two columns: $\Delta = (\Delta_1 + \Delta_2)/2$]	$\Delta = \pm h/500$
3	Inclination of any column that supports a crane gantry: 	Inclination from floor level to bearing of crane beam:	$\Delta = \pm h/1000$

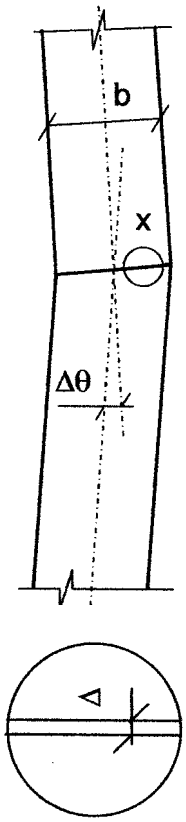
4	Straightness of a single storey column: 	Location of the column in plan, relative to a straight line between position points at top and bottom: - generally - structural hollow sections	$\Delta = \pm h/750$ $\Delta = \pm h/750$

D.1.12 Essential erection tolerances – Multi-storey columns

No	Criterion	Parameter	Permitted deviation Δ
1	Location at each storey level, relative to that at the base level: 	Location of the column in plan, at any storey level relative to a vertical line through its centre at base level:	$\Delta = \pm \Sigma h / (300\sqrt{n})$
2	Inclination of a column, between adjacent storey levels: 	Location of the column in plan, relative to a vertical line through its centre at the next lower level:	$\Delta = \pm h/500$

3	Straightness of a continuous column between adjacent storey levels: 	Location of the column in plan, relative to a straight line between position points at adjacent storey levels:	$\Delta = \pm h/750$
4	Straightness of a spliced column, between adjacent storey levels: 	Location of the column in plan at the splice, relative to a straight line between position points at adjacent storey levels:	$\Delta = \pm s/750$ with $s \leq h/2$
NOTE	Table D.1.12 multi-storey columns applies to that are continuous over more than one storey. Table D.1.11 single storey columns applies to storey-height columns in multi-storey buildings.		

D.1.13 Essential erection tolerances – Full contact end bearing

No	Criterion	Parameter	Permitted deviation Δ
1		Local angular misalignment Δθ occurring at the same time as gap Δ at point "X"	Δθ = ± *h*/500 where *h* is the storey height (see D.1.11 No4) and at the same time: • Δ = 0,5 mm over at least two thirds of the area, and • Δ = 1,0 mm maximum locally

D.1.14 Essential erection tolerances – Towers and masts

No	Criterion	Parameter	Permitted deviation Δ
1	Straightness of legs and chord components:	Straightness of portion (*L*) between joint locations.	*L*/1 000
2	Main dimensions of mast cross section and bracing:	Panel < 1 000 mm: Panel ≥ 1 000 mm:	Δ = ± 3 mm Δ = ± 5 mm
3	Position of centre of bracing components at joints:	Location relative to intended location	Δ = ± 3 mm
4	Alignment of centres of leg components in a leg joint:	Relative location of the two portions of the leg	Δ = ± 2 mm
5	Verticality of a mast:	Deviation from verticality of a line between any two points on the intended vertical axis of the structure, when measured in still air	Δ = ± 0,05 % but |Δ| ≥ 5 mm
6	Verticality of a tower:		Δ = ± 0,10 % but |Δ| ≥ 5 mm
7	Twist Δ over full height of structure [see NOTE 1]:	Structure < 150 m: Structure ≥ 150 m:	Δ = ± 2,0º Δ = ± 1,5 °
8	Twist Δ between adjacent levels of the structure [see NOTE 1]:	Structure < 150 m: Structure ≥ 150 m:	Δ = ± 0,10º per 3 metres Δ = ± 0,05º per 3 metres
NOTE 1 This twist criterion is not applicable to towers with permanent lateral loading. NOTE 2 Notations such as |Δ| = 0,10 % but |Δ| ≥ 5 mm mean that the *larger* of the two values is permitted.			

D.1.15 Essential erection tolerances – Beams subject to bending and components subject to compression

No	Criterion	Parameter	Permitted deviation
1	Straightness of beams subject to bending and components subject to compression if unrestrained	Deviation Δ from straightness	Δ = *L*/750

D.2 Functional tolerances

Permitted deviations for functional tolerances are tabulated:

D.2.1: Functional manufacturing tolerances – Welded profiles

D.2.2: Functional manufacturing tolerances – Press braked cold formed profiles

D.2.3: Functional manufacturing tolerances – Flanges of welded profiles

D.2.4: Functional manufacturing tolerances – Welded box sections

D.2.5: Functional manufacturing tolerances – Webs of welded profiles or box sections

D.2.6: Functional manufacturing tolerances – Web stiffeners of welded profiles or box sections

D.2.7: Functional manufacturing tolerances – Components

D.2.8: Functional manufacturing tolerances – Fasteners holes, notches and cut edges

D.2.9: Functional manufacturing tolerances – Column splices and baseplates

D.2.10: Functional manufacturing tolerances – Lattice components

D.2.11: Functional manufacturing tolerances – Stiffened plating

D.2.12: Functional manufacturing tolerances – Towers and masts

D.2.13: Functional manufacturing tolerances – Cold formed profiled sheets

D.2.14: Functional manufacturing tolerances – Bridge decks

D.2.15: Functional erection tolerances – Bridges

D.2.16: Functional erection tolerances – Bridge decks (sheet 1/3)

D.2.17: Functional erection tolerances – Bridge decks (sheet 2/3)

D.2.18: Functional erection tolerances – Bridge decks (sheet 3/3)

D.2.19: Functional manufacturing and erection tolerances – Crane beams and rails

D.2.20: Functional tolerances – Concrete foundations and supports

D.2.21: Functional erection tolerances – Crane runways

D.2.22: Functional erection tolerances – Positions of columns

D.2.23: Functional erection tolerances – Single storey columns

D.2.24: Functional erection tolerances – Multi-storey columns

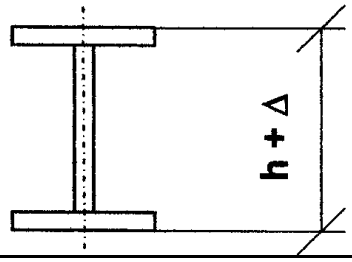
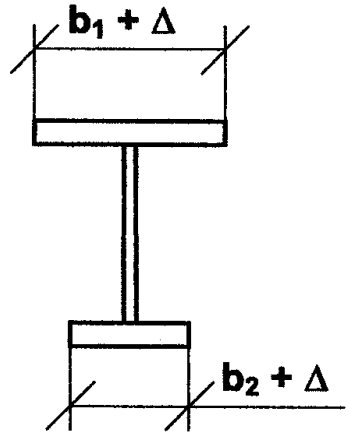
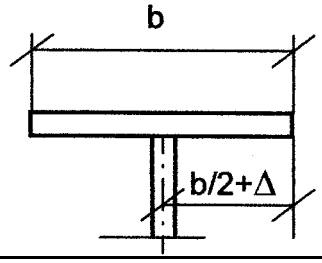
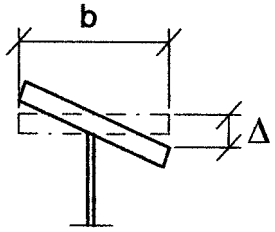
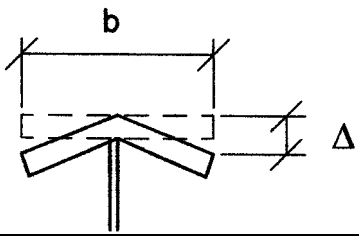
D.2.25: Functional erection tolerances – Buildings

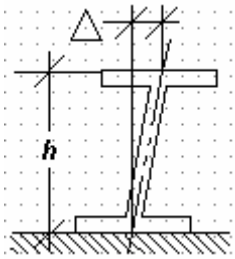
D.2.26: Functional erection tolerances – Beams in buildings

D.2.27: Functional erection tolerances – Roof sheeting designed as a stressed-skin

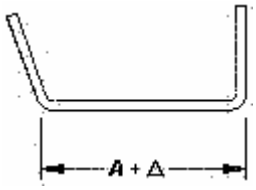
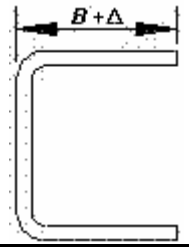
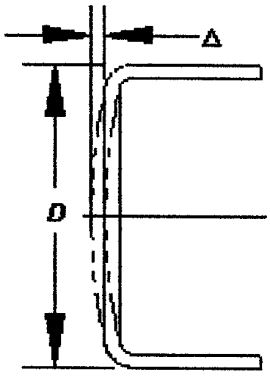
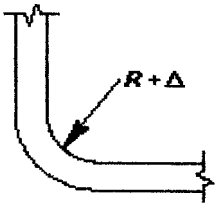
D.2.28: Functional erection tolerances – Profiled steel roofing

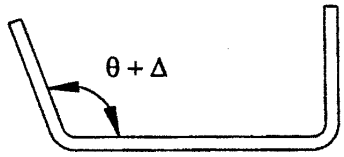
D.2.1 Functional manufacturing tolerances – Welded profiles

No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Depth: 	Overall depth h: $h \leq 900$ mm $900 < h \leq 1\,800$ mm $h > 1\,800$ mm	$\Delta = \pm 3$ mm $\Delta = \pm h/300$ $\Delta = \pm 6$ mm	$\Delta = \pm 2$ mm $\Delta = \pm h/450$ $\Delta = \pm 4$ mm
2	Flange width: 	Width b_1 or b_2	$+\ \Delta = b/100$ but $\lvert\Delta\rvert \geq 3$ mm	$+\ \Delta = b/100$ but $\lvert\Delta\rvert \geq 2$ mm
3	Web eccentricity: 	Position of web: - general case - flange parts in contact with structural bearings	$\Delta = \pm 5$ mm $\Delta = \pm 3$ mm	$\Delta = \pm 4$ mm $\Delta = \pm 2$ mm
4	Squareness of flanges: 	Out of squareness: - general case - flange parts in contact with structural bearings	$\Delta = \pm b/100$ but $\lvert\Delta\rvert \geq 5$ mm $\Delta = \pm b/400$	$\Delta = \pm b/100$ but $\lvert\Delta\rvert \geq 3$ mm $\Delta = \pm b/400$
5	Flatness of flanges: 	Out of flatness: - general case - flange parts in contact with structural bearings	$\Delta = \pm b/150$ but $\lvert\Delta\rvert \geq 3$ mm $\Delta = \pm b/400$	$\Delta = \pm b/150$ but $\lvert\Delta\rvert \geq 2$ mm $\Delta = \pm b/400$

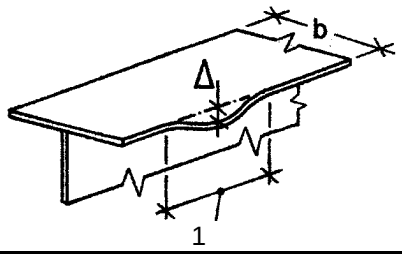
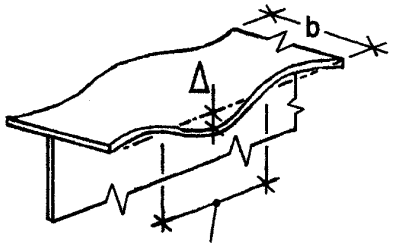
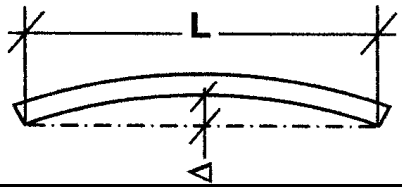
6	Squareness at bearings: 	Verticality of web at supports, for components without bearing stiffeners	$\Delta = \pm h/300$ but $\lvert\Delta\rvert \geq 3$ mm	$\Delta = \pm h/500$ but $\lvert\Delta\rvert \geq 2$ mm
NOTE Notations such as $\Delta = \pm d/100$ but $\lvert\Delta\rvert \geq 5$ mm mean that the *larger* of the two values is permitted.				

D.2.2 Functional manufacturing tolerances – Press braked cold formed profiles

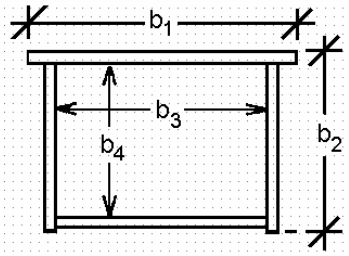
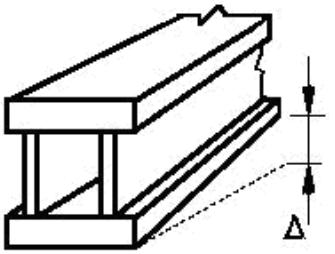
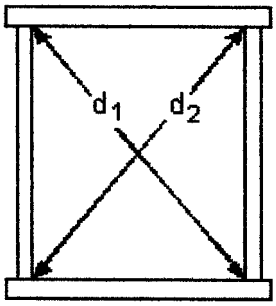
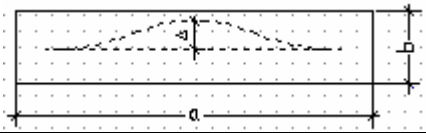
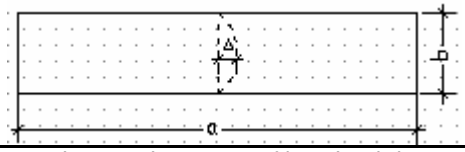
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Internal element width: 	Width *A* between bends: *t* < 3 mm: Length < 7 m Length ≥ 7 m *t* > 3 mm: Length < 7 m Length ≥ 7 m	 Δ = ± 3 mm Δ = - 3 mm / + 5 mm Δ = ± 5 mm Δ = - 5 mm / + 9 mm	 Δ = ± 2 mm Δ = - 2 mm / + 4 mm Δ = ± 3 mm Δ = - 3 mm / + 6 mm
2	Outstand element width: 	Width *B* between a bend and a free edge: - Mill edge: *t* < 3 mm *t* > 3 mm - Sheared edge: *t* < 3 mm *t* > 3 mm	 Δ = - 3 mm / + 6 mm Δ = - 5 mm / + 7 mm Δ = - 2 mm / + 5 mm Δ = - 3 mm / + 6 mm	 Δ = - 2 mm / + 4 mm Δ = - 3 mm / + 5 mm Δ = - 1 mm / + 3 mm Δ = - 2 mm / + 4 mm
3	Flatness: 	Convexity or concavity	Δ = ± *D*/50	Δ = ± *D*/100
4	Bend radius: 	Internal bend radius *R*	Δ = ± 2 mm	Δ = ± 1 mm

5	Shape:  	Angle θ between adjacent components	$\Delta = \pm 3°$	$\Delta = \pm 2°$

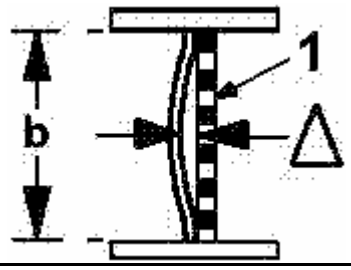
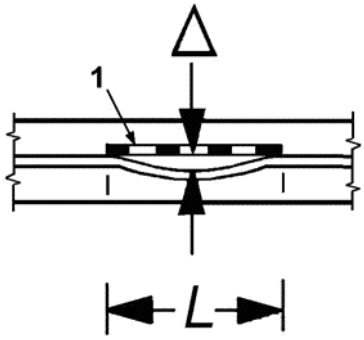
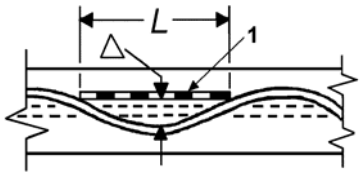
D.2.3 Functional manufacturing tolerances – Flanges of welded profiles

No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Flange distortion of I section:  	Distortion Δ on gauge length = flange width *b*	Δ = ± *b* / 100	Δ = ± *b* / 150
2	Flange undulation of I section  	Distortion Δ on gauge length = flange width *b*	Δ = ± *b* / 100	Δ = ± *b* / 150
3	Flange straightness:  	Deviation Δ from straightness	Δ = ± *L* / 500	Δ = ± *L* / 1 000
Key 1 gauge length				

D.2.4 Functional manufacturing tolerances – Welded box sections

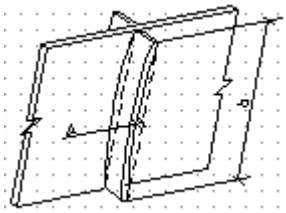
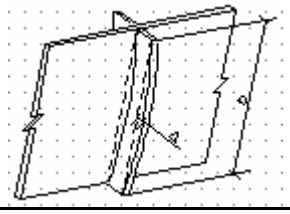
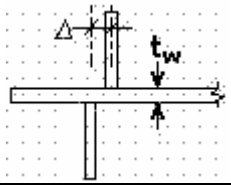
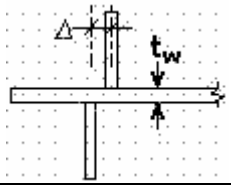
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Plate widths: 	Deviation in internal or external dimensions: b < 900 mm 900 mm < b < 1 800 mm b > 1 800 mm where $b = b_1, b_2, b_3$ or b_4	Δ = ± 3 mm Δ = ± b/300 Δ = ± 6 mm	Δ = ± 2 mm Δ = ± b/450 Δ = ± 4 mm
2	Twist: 	Overall deviation Δ in a piece of length L	Δ = ± L/700 but 4 mm ≤ |Δ| ≤ 10 mm	Δ = ± L/1 000 But 3 mm ≤ |Δ| ≤ 8 mm
3	Squareness: 	Difference Δ between diagonal dimensions at diaphragm positions: Δ = |$d_1 - d_2$|	Δ = (d_1+d_2)/400 but Δ ≥ 6 mm	Δ = (d_1+d_2)/600 but Δ ≥ 4 mm
		Where d_1 and d_2 are significantly different: $\Delta = \left\| (d_1 - d_2)_{actual} - (d_1 - d_2)_{intended} \right\|$		
4	Out of plane imperfections of plate panels between webs or stiffeners, general case: 	Distortion Δ perpendicular to the plane of the plate: if $a \le 2b$ if $a > 2b$	Δ = ± a/250 Δ= ± b/125	Δ = ± a/250 Δ= ± b/125
5	Out of plane imperfections of plate panels between webs or stiffeners, (special case with compression in the transverse direction – the general case applies unless this special case is specified): 	Distortion Δ perpendicular to the plane of the plate: if $b \le 2a$ if $b > 2a$	Δ = ± b/250 Δ = ± a/125	Δ = ± b/250 Δ = ± a/125
NOTE Notations such as Δ = ± d/100 but |Δ| ≥ 5 mm mean that the *larger* of the two values is permitted.				

D.2.5 Functional manufacturing tolerances – Webs of welded profiles or box sections

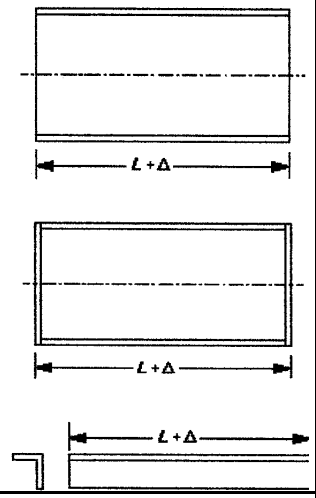
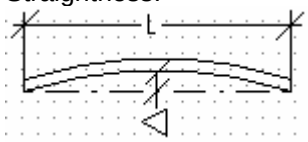
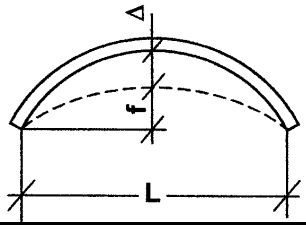
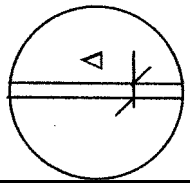
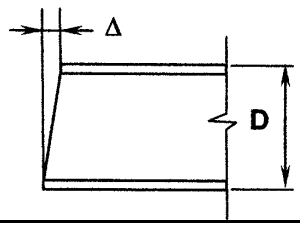
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Web curvature: 	Deviation Δ on the web heigth *b*	Δ = ± *b*/100 but |Δ| ≥ 5 mm	Δ = ± *b*/150 but |Δ| ≥ 3 mm
2	Plate distortion: 	Deviation Δ on gauge length *L* = web heigth *b*	Δ = ± *b* /100 but |Δ| ≥ 5 mm	Δ = ± *b* /150 but |Δ| ≥ 3 mm
3	Plate undulation: 	Deviation Δ on gauge length *L* = web heigth *b*	Δ = ± *b* /100 but |Δ| ≥ 5 mm	Δ = ± *b* /150 but |Δ| ≥ 3 mm
4	Castellated beams and cellular beams (fabricated either from plate or from hot-rolled sections) with openings of inscribed nominal diameter *D*	Misalignment of web post: - across thickness - overlap for opening of nominal radius *r*: *r* = *D*/2 < 200 mm *r* = *D*/2 ≥ 200 mm	 Δ = ± 2 mm Δ = ± 2 mm Δ = ± *r*/100 ≤ 5 mm	 Δ = ± 2 mm Δ = ± 2 mm Δ = ± *r*/100 ≤ 5 mm

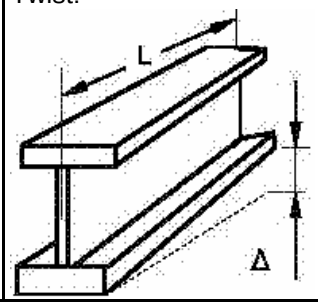
Key
1 gauge length
NOTE: Notations such as Δ = ± *d*/100 but |Δ| ≥ 5 mm mean that the *larger* of the two values is permitted.

D.2.6 Functional manufacturing tolerances – Web stiffeners of welded profiles or box sections

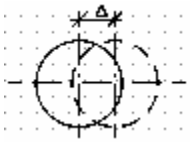
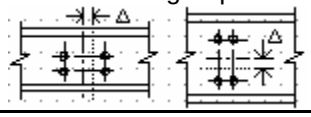
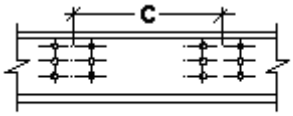
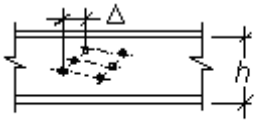
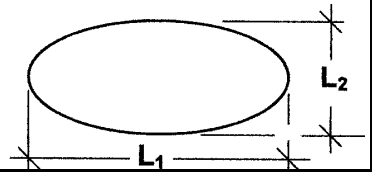
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	In plane straightness: 	Deviation Δ from straightness in the plane of the web	Δ = ± *b* /250 but |Δ| ≥ 4 mm	Δ = ± *b* /375 but |Δ| ≥ 2 mm
2	Out of plane straightness: 	Deviation Δ from straightness normal to the plane of the web	Δ = ± *b* /500 but |Δ| ≥ 4 mm	Δ = ± *b* /750 but |Δ| ≥ 2 mm
3	Location of web stiffeners: 	Distance from intended location	Δ = ± 5 mm	Δ = ± 3 mm
4	Location of web stiffeners at support: 	Distance from intended location	Δ = ± 3 mm	Δ = ± 2 mm
5	Eccentricity of web stiffeners: 	Eccentricity between a pair of stiffeners	Δ = ± t_w /2	Δ = ± t_w/3
6	Eccentricity of web bearing stiffeners at supports: 	Eccentricity between a pair of stiffeners	Δ = ± t_w/3	Δ = ± t_w/4
NOTE Notations such as Δ = ± *d* /100 but |Δ| ≥ 5 mm mean that the *larger* of the two values is permitted.				

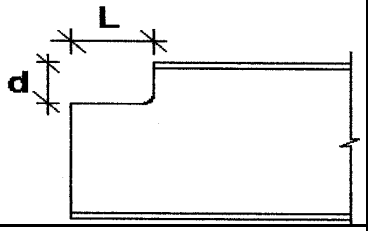
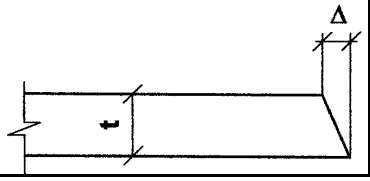
D.2.7 Functional manufacturing tolerances – Components

No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Length:  	Cut length measured on the centreline (or on the corner for an angle) : - general case: - ends ready for full contact bearing: NOTE Length *L* measured including welded end plates as applicable.	Δ = ± (*L*/5 000 + 2) mm Δ = ± 1 mm	Δ=± (*L*/10 000 + 2) mm Δ = ± 1 mm
2	Length, where sufficient compensation with next component is possible:	Cut length measured on centreline:	Δ = ± 50 mm	Δ = ± 50 mm
3	Straightness:  	Deviation Δ from rectangular axes of a fabricated or press braked section: NOTE For rolled or hot finished sections see the relevant product standard.	Δ = ± L/500 but |Δ| ≥ 5 mm	Δ = ± L/750 but |Δ| ≥ 3 mm
4	Camber or intended curvature on plan:  	Offset *f* at mid-length: NOTE Vertical camber should be measured with the member on its side.	Δ = ± L/500 but |Δ| ≥ 6 mm	Δ = ± L/1000 but |Δ| ≥ 4 mm
5	Surfaces finished for full contact bearing: 	Gap Δ between straight edge and surface: NOTE No surface roughness criterion is specified.	Δ = 0,5 mm high spots not be proud by more than 0,5 mm.	Δ = 0,25 mm high spots not be proud by more than 0,25 mm.
6	Squareness of ends:  	Squareness to longitudinal axis: - ends intended for full contact bearing: - ends not intended for full contact bearing:	Δ = ± *D* /1 000 Δ = ± *D* /100	Δ = ± *D* /1 000 Δ = ± *D* /300 but |Δ| ≤ 10 mm

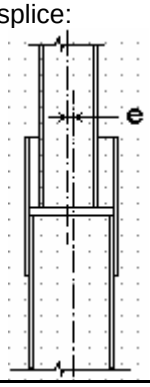
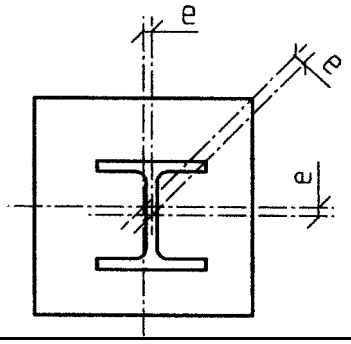
7	Twist:  	Overall deviation Δ in a piece of length *L:* NOTE 1 For box sections see Table D.2.4. NOTE 2 For structural hollow sections see the relevant product standard.	Δ = ± *L* / 700 But 4 mm ≤ |Δ| ≤ 20 mm	Δ = ± *L* / 1 000 but 3 mm ≤ |Δ| ≤ 15 mm
NOTE Notations such as Δ = ± *d* /100 but |Δ| ≥ 5 mm mean that the *larger* of the two values is permitted.				

D.2.8 Functional manufacturing tolerances – Fastener holes, notches and cut edges

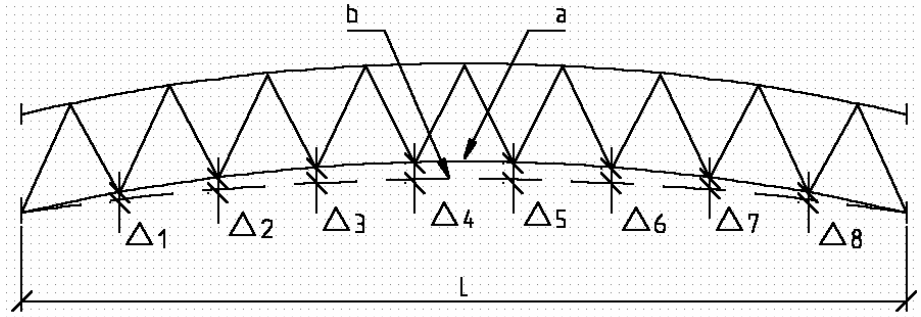
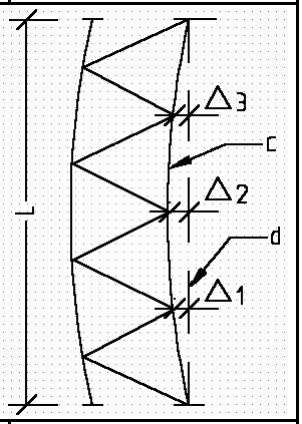
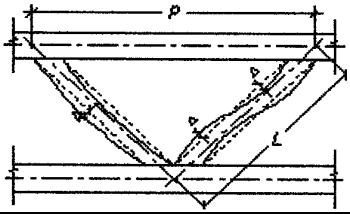
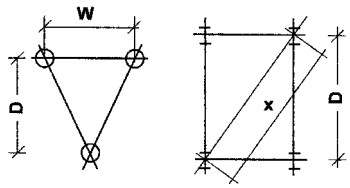
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Position of holes for fasteners:  	Deviation Δ of centreline of an individual hole from its intended position within a group of holes:	Δ = ± 2 mm	Δ = ± 1 mm
2	Position of holes for fasteners:  	Deviation Δ in distance *a* between an individual hole and a cut end:	- Δ = 0 + Δ ≤ 3 mm	- Δ = 0 + Δ ≤ 2 mm
3	Position of hole group:  	Deviation Δ of a hole group from its intended position:	Δ = ± 2 mm	Δ = ± 1 mm
4	Spacing of hole groups:  	Deviation Δ in spacing *c* between centres of hole groups: - general case - where a single piece is connected by two groups of fasteners:	Δ = ± 5 mm Δ = ± 2 mm	Δ = ± 2 mm Δ = ± 1 mm
5	Twist of a hole group:  	Twist Δ: - if *h* ≤ 1 000 mm - if *h* > 1 000 mm	Δ = ± 2 mm Δ = ± 4 mm	Δ = ± 1 mm Δ = ± 2 mm
6	Ovalisation of holes:  	Δ = L_1 - L_2	Δ **= ±** 1 mm	Δ **= ±** 0,5 mm

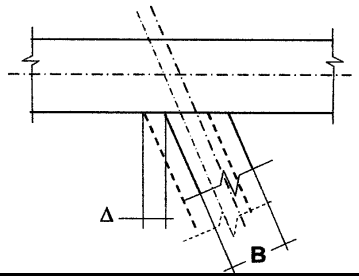
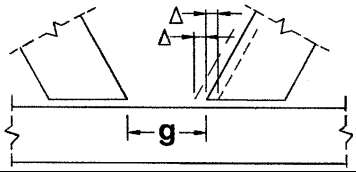
7	Notches: 	Deviation Δ of notch depth and length: - depth *d* - length *L*	- Δ = 0 mm + Δ ≤ 3 mm - Δ = 0 mm + Δ ≤ 3 mm	- Δ = 0 mm + Δ ≤ 2 mm - Δ = 0 mm + Δ ≤ 2 mm
8	Squareness of cut edges: 	Deviation Δ of a cut edge from 90°	Δ = ± 0,1*t*	Δ = ± 0,05*t*

D.2.9 Functional manufacturing tolerances – Column splices and baseplates

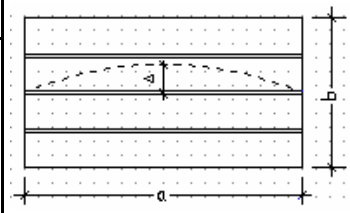
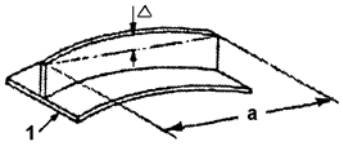
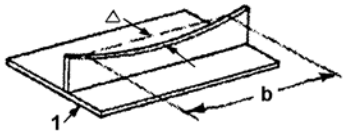
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Column splice: 	Non-intended eccentricity *e* (about either axis):	5 mm	3 mm
2	Baseplate: 	Non-intended eccentricity *e* (in any direction):	5 mm	3 mm

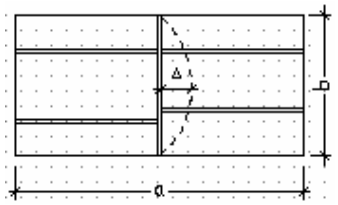
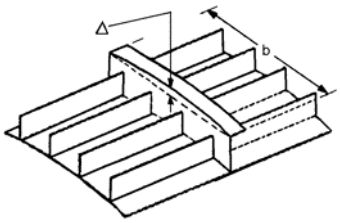
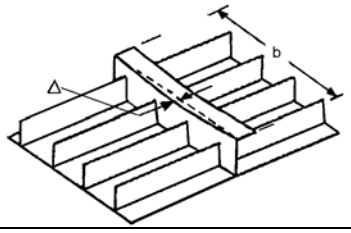
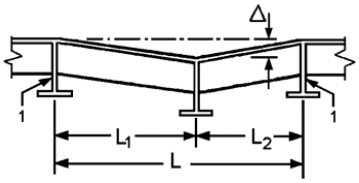
D.2.10 Functional manufacturing tolerances – Lattice components

No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Straightness and camber:  NOTE Deviations measured after welding, with the component lying flat on its side.  **Key** *a* actual camber *b* intended camber *c* actual line *d* intended line	Deviation at each panel point, relative to a straight line - or to the intended camber or curvature.	$\Delta = \pm L/500$ but $\lvert\Delta\rvert \geq 12$ mm	$\Delta = \pm L/500$ but $\lvert\Delta\rvert \geq 6$ mm
2	Panel dimensions:  	Deviation of individual distances *p* between intersections of centre lines at panel points:	$\Delta = \pm 5$ mm	$\Delta = \pm 3$ mm
		Cumulative deviation Σp of panel point position:	$\Delta = \pm 10$ mm	$\Delta = \pm 6$ mm
3	Straightness of bracing components:	Deviation of bracing from straightness:	$\Delta = \pm L/500$ but $\lvert\Delta\rvert \geq 6$ mm	$\Delta = \pm L/1\,000$ but $\lvert\Delta\rvert \geq 3$ mm
4	Cross-sectional dimensions:  	Deviation of distances *D*, *W* and *X* if: $s \leq 300$ mm: $300 < s < 1\,000$ mm $s \geq 1\,000$ mm NOTE *s* = *D*, *W* or *X* as appropriate.	$\Delta = \pm 3$ mm $\Delta = \pm 5$ mm $\Delta = \pm 10$ mm	$\Delta = \pm 2$ mm $\Delta = \pm 4$ mm $\Delta = \pm 6$ mm

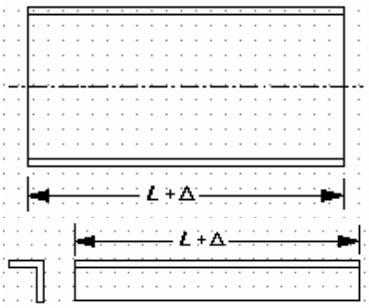
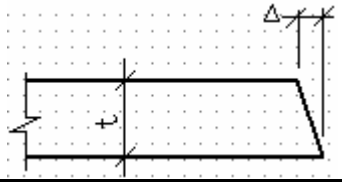
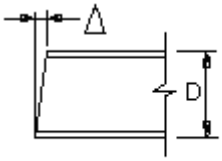
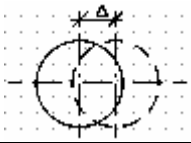
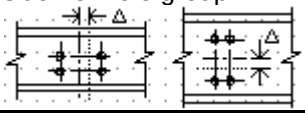
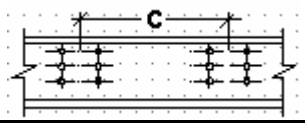
5	Intersecting joints:  	Eccentricity (relative to specified eccentricity):	Δ = ± (B/20 + 5) mm	Δ = ± (B/40 + 3) mm
6	Gap joints:  	Gap *g* between bracing components: g ≥ (t1 + t2) where t1 and t2 are the wall thicknesses of braces	$\|\Delta\| = \pm (t_1 + t_{2)}$ but $\|\Delta\| \leq 5$ mm	$\|\Delta\| = \pm (t_1 + t_{2)}$ but $\|\Delta\| \leq 3$ mm
NOTE Notation such as Δ = ± L/500 but $\|\Delta\| \geq 6$ mm means that the *larger* of the two values is permitted. Notation such as Δ = ± (t1 + t2) but $\|\Delta\| \leq 5$ mm means that the *smaller* of the two values is required.				

D.2.11 Functional manufacturing tolerances – Stiffened plating

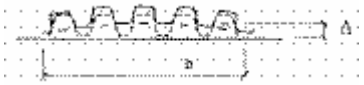
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Straightness of stiffeners: Longitudinal stiffeners in longitudinally stiffened plating  **Key** 1 plate	Deviation Δ perpendicular to the plate:  	Δ = ± *a*/400	Δ = ± *a* / 750 but $\|\Delta\| \geq 2$ mm
2		Deviation Δ parallel to the plate:  	Δ = ± *b* / 400	Δ = ± *b* / 500

3	Straightness of stiffeners: Transverse stiffeners in transversely and longitudinally stiffened plating:  	Deviation Δ perpendicular to the plate:  	Smaller of: $\Delta = \pm a / 400$ or $\Delta = \pm b / 400$	Smaller of: $\Delta = \pm a / 500$ or $\Delta = \pm b / 750$ but $\lvert\Delta\rvert \geq 2$ mm
4		Deviation Δ parallel to the plate:  	$\Delta = \pm b / 400$	$\Delta = \pm b / 500$
5	Levels of cross frames in stiffened plating: **Key** 1 **cross frame**	Level relative to adjacent cross frames:  	$\Delta = \pm L / 400$	$\Delta = \pm L / 500$ but $\lvert\Delta\rvert \geq 2$ mm

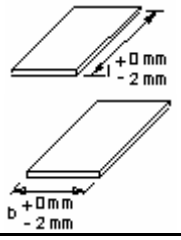
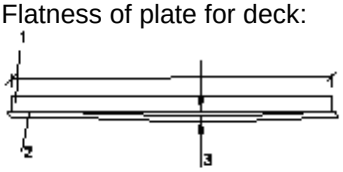
D.2.12 Functional manufacturing tolerances – Towers and masts

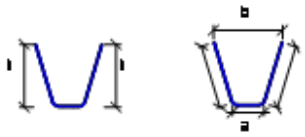
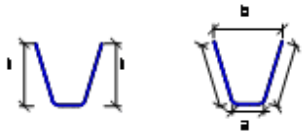
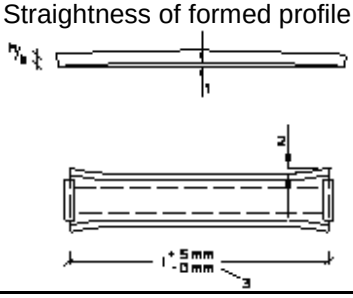
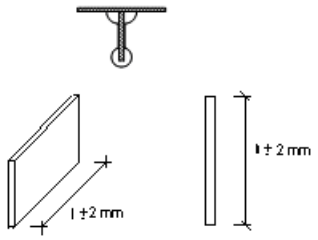
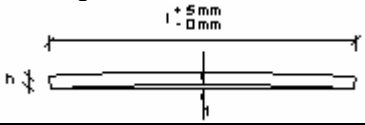
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Length of components: 	Cut length measured on the centreline (or on the corner for an angle):	Δ = ± 1 mm	Δ = ± 1 mm
2	Length or spacing:	If minimum dimensions are specified:	- Δ = 0 mm + Δ ≤ 1 mm	- Δ = 0 mm + Δ ≤ 1 mm
3	Back marks for angles:	Distance from heel of angle to centre of hole:	Δ = ± 0,5 mm	Δ = ± 0,5 mm
4	Squareness of cut edges: 	Deviation Δ of a cut edge from 90°:	Δ = ± 0,05*t*	Δ = ± 0,05*t*
5	Squareness of ends: 	Squareness to longitudinal axis: - ends intended for full contact bearing: - ends not intended for full contact bearing:	Δ = ± *D* /1 000 Δ = ± *D* /300	Δ = ± *D* /1 000 Δ = ± *D* /300
6	Surfaces intended for full contact in bearing:	Flatness:	1 in 1 500	1 in 1 500
7	Position of holes for fasteners: 	Deviation Δ of centreline of an individual hole from its intended position within a group of holes:	Δ = ± 2 mm	Δ = ± 1 mm
8	Position of hole group: 	Deviation Δ of a hole group from its intended position:	Δ = ± 2 mm	Δ = ± 1 mm
9	Spacing of hole groups: 	Deviation Δ in spacing *c* between centres of hole groups:	Δ = ± 1 mm	Δ = ± 0,5 mm
NOTE Notations such as Δ = ± 0,10 % but |Δ| ≥ 5 mm mean that the *larger* of the two values is permitted.				

D.2.13 Functional manufacturing tolerances – Cold formed profiled sheets

No	Criterion	Parameter	Permitted deviation Δ
1	Vertical curvature of the sheet: 	Deviation Δ from the intended shape over the sheet width *b*	$\Delta \leq \pm b/100$
2	Shape:	Deviation Δ in intended angle between adjacent elements of the cross-section	$\Delta \leq \pm 3°$

D.2.14 Functional manufacturing tolerances – Bridge decks

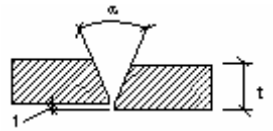
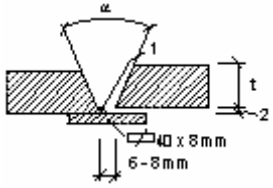
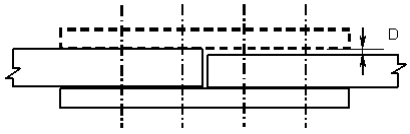
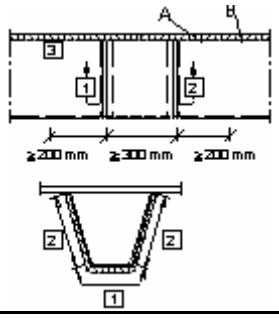
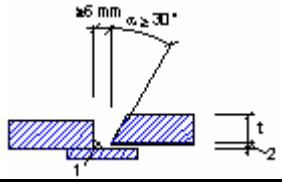
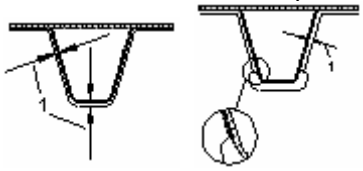
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Length / depth / width of plate for deck: 	Overall dimensions *l*, *b* after cutting and straightening by rolling inclusive of provisions for shrinkage and after application of the final weld preparation	No requirement	$0 \geq \Delta \geq -2$ mm (no positive value given)
2	Flatness of plate for deck: 	After application of the final weld preparation **Key** 1 gauge length 2 000 mm 2 plate 3 fit up gap Δ	Class S according to EN 10029	$\Delta = \pm 2$ mm

3	Formed profile for passing through crossbeams: with cope holes 	Height *h*, width *a* and *b* Note for *a* or *b*: If the tolerances are exceeded, the cut outs in the crossbeams are to be adapted to meet maximum gap width measured at a distance of at least 500 mm from the end	Δh = ± 3 mm Δa = ± 2 mm Δb = ± 3 mm	+ 2 mm ≥ Δ(*h* or *a* or *b*) ≥ -1 mm
	without cope holes 	Note for *b*: If the tolerances are exceeded, the cut outs in the crossbeams are to be adapted to meet maximum gap width measured at a distance of at least 500 mm from the end	Δh = ± 2 mm Δa = ± 1 mm Δb = ± 2,5 mm	Δ = ± 0,5 mm
4	Straightness of formed profile: 	**Key** 1 max. gap Δ_1 2 max widening Δ_2 3 for stiffener splices with splice plates Δ_3 radius r = r ± Δ_r rotation Δ_φ measured on a plane surface over 4 m length parallelism Δ_p	Δ_1 = ± L/500 Δ_2 = 5 mm 5 mm ≥ Δ_3 ≥ 0 Δ_r = ± 0,20 r Δ_φ = ± 1° Δ_p = ± 2 mm	Δ_1 = ± L/1000 Δ_2 = 1 mm 5 mm ≥ Δ_3 ≥ 0 Δ_r = ± 2 mm Δ_φ = ±1° Δ_p = ±2 mm
5	Length / width of flat profile for welding on both sides: 	Overall dimensions l, h	Δ = ± 2 mm	Δ = ± 2 mm
6	Straightness of flat profile for welding on both sides: 	**Key** 1 max. gap Δ_1 Length Δ_l	Δ_1 = ± L/1 000 5 mm ≥ Δ_l ≥ 0	Δ_1 = ± L/1 000 5 mm ≥ Δ_l ≥ 0

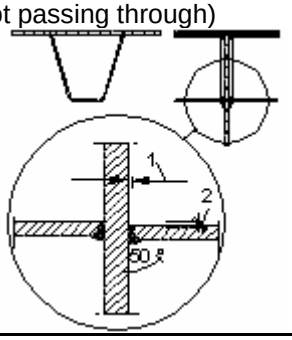
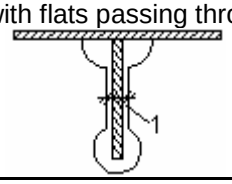
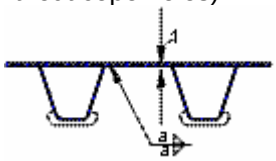
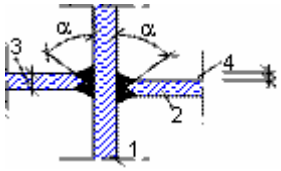
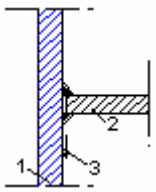
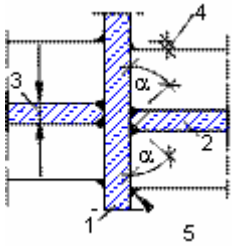
D.2.15 Functional erection tolerances – Bridges

No	Criterion	Parameter	Permitted deviation Δ
1	Span length:	Deviation Δ of distance L between two consecutive supports measured on top of upper flange:	$\Delta = \pm (30 + L / 10\,000)$
2	Bridge elevation or plan profile:	Deviation Δ from nominal profile taking into account as-built levels of supports: $L \leq 20$ m: $L > 20$ m:	 $\Delta = \pm (L / 1\,000)$ $\Delta = \pm (L / 2\,000 + 10\text{ mm}) \leq 35$ mm

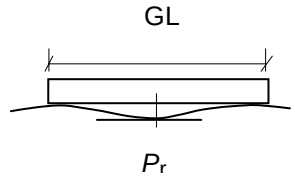
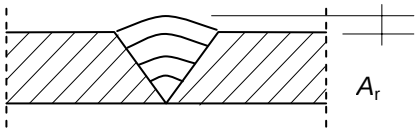
D.2.16 Functional erection tolerances – Bridge decks (sheet 1/3)

No	Criterion	Parameter	Permitted deviation Δ
1	Splices of deck plate without backing strip or splice of lower flange or web of crossbeam: 	**Key** 1 misalignment Δ before welding	Δ = ± 2 mm
2	Splices of deck plate with backing strip: 	**Key** 1 tack weld 2 misalignment Δ before welding Fit up gaps Δ_g between plate and backing strip after welding	Δ = ± 2 mm $\lvert\Delta_g\rvert$ = 1 mm
3	Stiffener-deck plate connection: 	Root penetration Fit up gap	Δ = ± 2 mm
4	Stiffener-stiffener connection with splice plates: 	Misalignment Δ between stiffener and splice plate before welding	Δ = ± 2 mm
5	Stiffener to stiffener connection with splice plates: 	**Key** 1 continuous tack weld 2 misalignment Δ before welding	Δ = ± 2 mm
6	Stiffener-crossbeam connec-tion with stiffeners passing through the crossbeam with or without cope holes 	**Key** 1 max. gap Δ_1 minimum throat thickness a: for gap width s ≤ 2 mm: a = a_{nom} according to analysis for gap widths s > 2 mm: a = a_{nom} + (s-2) But a ≥ 4 mm	Δ_1 = 3 mm

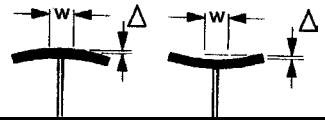
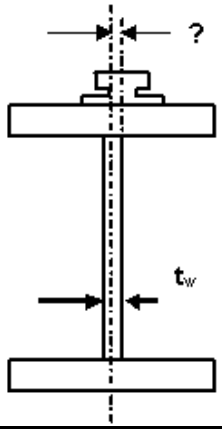
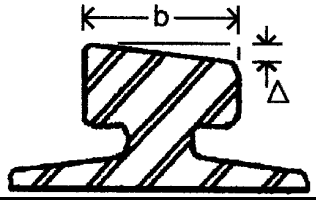
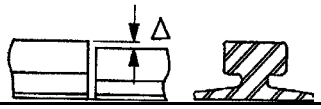
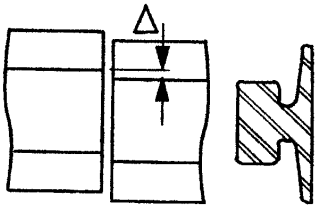
D.2.17 Functional erection tolerances – Bridge decks(sheet 2/3)

1	Stiffener-crossbeam connection with stiffeners fitted between crossbeams (not passing through) 	**Key** 1 max. gap Δ_1 2 misalignment Δ_2 before welding	Δ_1 = 2 mm Δ_2 = ± 2 mm
2	Stiffener-crossbeam connection with flats passing through 	**Key** 1 max. gap Δ	Δ = 1 mm
3	Connection of web of crossbeam to deck plate (with or without cope holes) 	**Key** 1 max. gap Δ	Δ = 1 mm
4	Connection of webs of crossbeams to web of main girder a) for continuous crossbeams  b) for non continuous crossbeams 	**Key** 1 web of main girder 2 web of crossbeam 3 in fig. a) $t_{w,crossb}$ 3 in fig. b) gap Δ_b 4 misalignment Δ_a before welding	a) Δ_a = ± 0,5 $t_{w,crossb}$ b) Δ_b = ± 2 mm
5	Connection of crossbeam flanges to web of main girder 	Key 1 web of main girder 2 web of crossbeam 3 $t_{w,crossb}$ 4 misalignment Δ before welding	Δ = ± 0,5 $t_{w,crossb}$

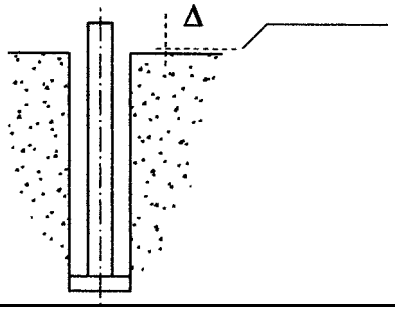
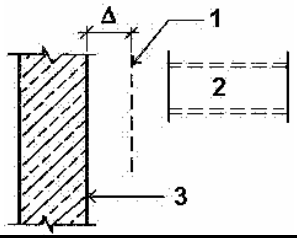
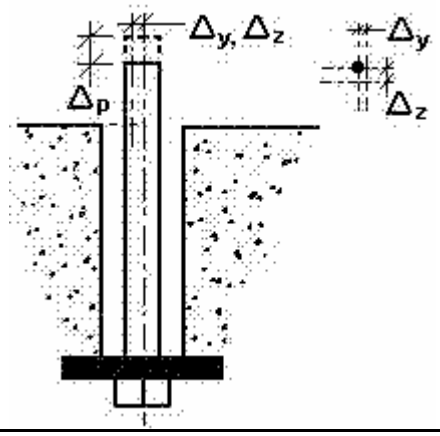
D.2.18 Functional erection tolerances – Bridges decks (sheet 3/3)

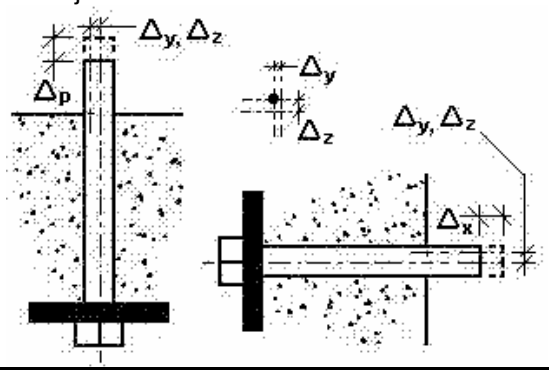
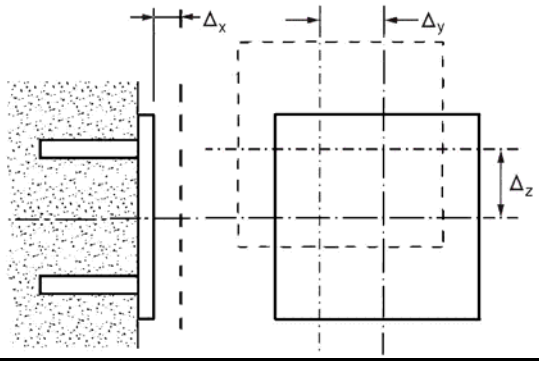
No	Criterion	Parameter	Permitted deviation Δ
1	Fit-up of orthotropic decks of plate thickness *t* after erection:  **Key** GL gauge length P_r deviation V_e step D_r slope	Difference in level at junction: $t \leq 10$ mm: 10mm < $t \leq 70$ mm $t > 70$ mm: Slope at junction: $t \leq 10$ mm: 10 mm < $t \leq 70$ mm: $t > 70$ mm: Flatness in all directions: $t \leq 10$ mm: $t > 70$ mm: General case: Longitudinally: NOTE Values for P_r may be interpolated for 10 mm < $t \leq 70$ mm.	 V_e = 2 mm V_e = 5 mm V_e = 8 mm D_r = 8 % D_r = 9 % D_r = 10 % P_r = 3 mm over gauge length 1 m P_r = 4 mm over gauge length 3 m P_r = 5 mm over gauge length 5 m P_r = 5 mm over gauge length 3 m P_r = 18 mm over gauge length 3 m
2	Orthotropic deck welding:  	Protrusion A_r of weld above surrounding surface:	A_r = - 0 mm / + 1 mm

D.2.19 Functional manufacturing and erection tolerances – Crane beams and rails

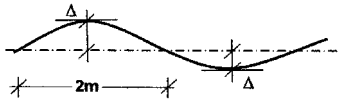
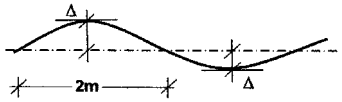
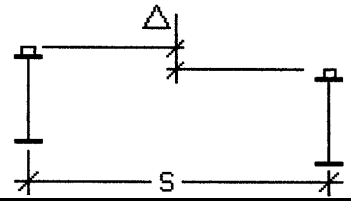
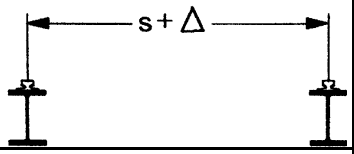
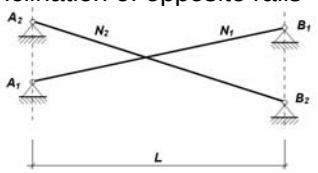
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Flatness of top flange of a crane beam: 	Out of flatness over a central width *w* equal to the rail width plus 10 mm either side of rail in nominal position:	Δ = ± 1 mm	Δ = ± 1 mm
2	Eccentricity of rail relative to web: 	For $t_w \leq 10$ mm For $t_w > 10$ mm	± 5 mm ± 0,5 t_w	± 5 mm ± 0,5 t_w
3	Slope of rail: 	Slope of top surface of cross-section:	Δ = ± *b*/100	Δ = ± *b* / 100
4	Level of rail: 	Step in top of rail at joint:	Δ = ± 1 mm	Δ = ± 0,5 mm
5	Edge of rail: 	Step in edge of rail at joint:	Δ = ± 1 mm	Δ = ± 0,5 mm

D.2.20 Functional tolerances – Concrete foundations and supports

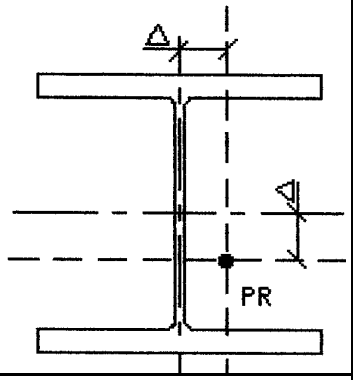
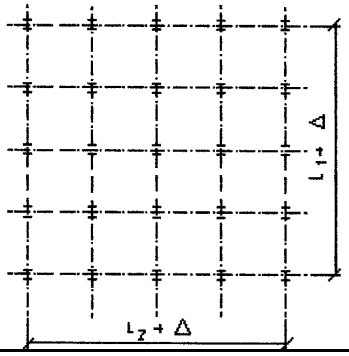
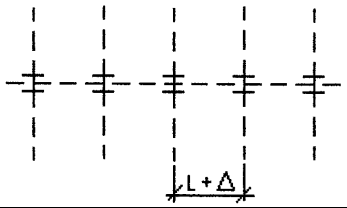
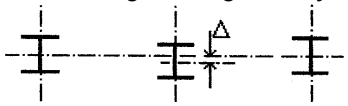
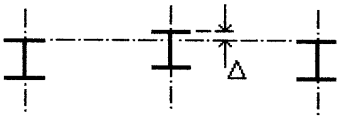
No	Criterion	Parameter	Permitted deviation Δ
1	Foundation level: 	Deviation Δ from specified level:	- 15 mm ≤ Δ ≤ + 5 mm
2	Vertical wall:  Key 1 specified position 2 steel component 3 supporting wall	Deviation Δ from specified position at support point for steel component:	Δ = ± 25 mm
3	Pre-set foundation bolt where prepared for adjustment: 	Deviation Δ from specified location and protrusion: - location at tip: - vertical protrusion Δ_p: NOTE The permitted deviation for location of the centre of a bolt group is 6 mm.	Δ_y, Δ_z = ± 10 mm - 5 mm ≤ Δ_p ≤ + 25 mm

4	Pre-set foundation bolt where not prepared for adjustment: 	Deviation Δ from specified location, level and protrusion: - location or level at tip: - vertical protrusion Δ_p: - horizontal protrusion Δ_x: NOTE The permitted deviation for location also applies to the centre of a bolt group.	Δ_y, Δ_z = ± 3 mm - 5 mm ≤ Δ_p ≤ 45 mm - 5 mm ≤ Δ_x ≤ 45 mm
5	Steel anchor plate embedded in concrete: 	Deviations Δx, Δy, Δz from the specified location and level:	Δx, Δy, Δz = ± 10 mm

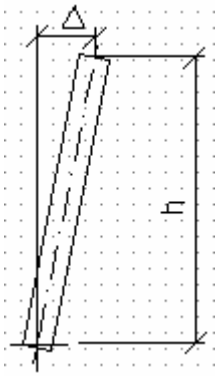
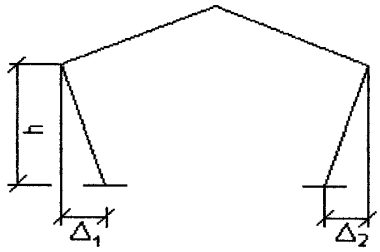
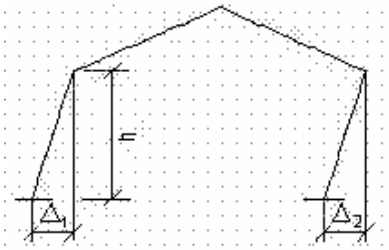
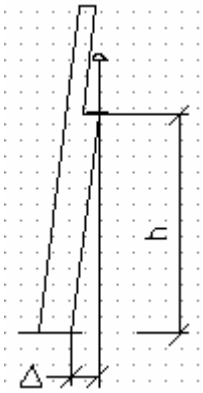
D.2.21 Functional erection tolerances – Crane runways

No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Location of rail in plan:	Relative to the intended location:	Δ = ± 10 mm	Δ = ± 5 mm
2	Local alignment of rail: 	Alignment over 2 m gauge length:	Δ = ± 1,5 mm	Δ = ± 1 mm
3	Level of rail	Relative to the intended level:	Δ = ± 15 mm	Δ = ± 10 mm
4	Level of rail	Level over span *L* of crane beam:	Δ = ± *L* / 500 but |Δ| ≥ 10 mm	Δ = ± *L* / 1 000 but |Δ| ≥ 10 mm
5	Level of rail: 	Variation over 2 m gauge length:	Δ = ± 3 mm	Δ = ± 2 mm
6	Relative levels of rails on the two sides of a runway: 	Deviation of level: for *s* ≤ 10 m for *s* > 10 m	Δ = ± 20 mm Δ = ± *s* / 500	Δ = ± 10 mm Δ = ± *s* / 1 000
7	Spacing *s* between centres of crane rails: 	Deviation of spacing: for *s* ≤ 16 m for *s* > 16 m	Δ = ± 10 mm Δ = ± (10 + [*s* - 16]/3) mm, with *s* in m and result in mm	Δ = ± 5 mm Δ = ± (5 + [*s* - 16]/4) mm, with *s* in m and result in mm
8	Structural end stops:	Relative location of the stops at the same end, measured in the direction of travel on the runway:	Δ = ± *s* / 1 000 but |Δ| ≤ 10 mm	Δ = ± *s* / 1 000 but |Δ| ≤ 10 mm
9	Inclination of opposite rails  $\|\Delta\| = \|N_1 - N_2\|$ **Key** N_1 inclination A_1 B_1 N_2 inclination A_2 B_2 *L* distance of adjacent supports	Offset	Δ = *L* / 500	Δ = *L* / 1 000

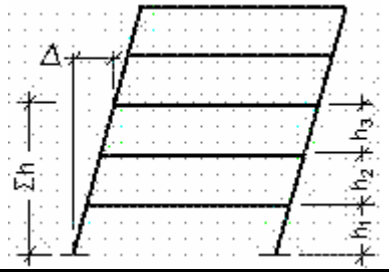
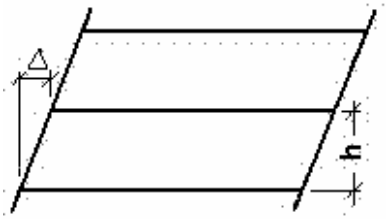
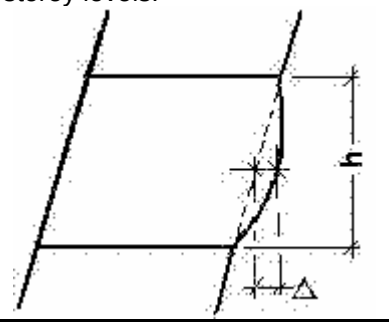
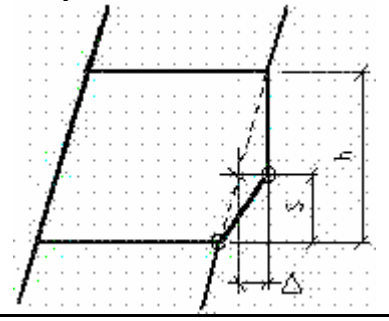
D.2.22 Functional erection tolerances – Positions of columns

No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Location: 	Location in plan of the centre of the column at the level of its base, relative to the position point of reference (PR)	Δ = ± 10 mm	Δ = ± 5 mm
2	Overall length of a building: 	Distance between end columns in each line, at base level: $L \leq 30$ m 30 m < L < 250 m $L \geq 250$ m	Δ = ± 20 mm Δ = ± 0,25(L+50) mm Δ = ± 0,1(L+500) mm [L in metres]	Δ = ± 16 mm Δ = ± 0,2(L+50) mm Δ = ± 0,1(L+350) mm [L in metres]
3	Column spacing: 	Distance between centres of adjacent columns at base level: $L \leq 5$ m $L > 5$ m	Δ = ± 10 mm Δ = ± 0,2(L+45) mm [L in metres]	Δ = ± 7 mm Δ = ± 0,2(L+30) mm [L in metres]
4	Column alignment generally: 	Location of the centre of the column at base level, relative to the established column line (ECL)	Δ = ± 10 mm	Δ = ± 7 mm
5	Perimeter column alignment: 	Location of the outer face of a perimeter column at base level, relative to the line joining the faces of the adjacent columns	Δ = ± 10 mm	Δ = ± 7 mm

D.2.23 Functional erection tolerances – Single storey columns

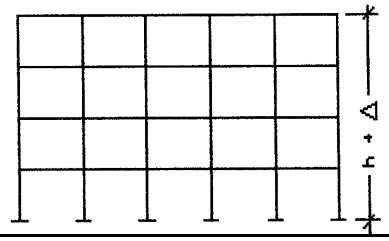
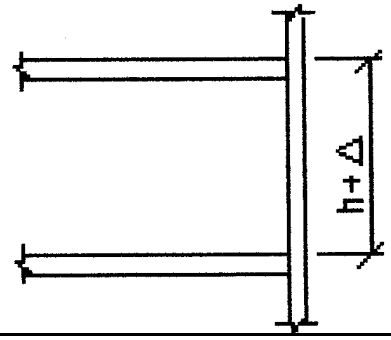
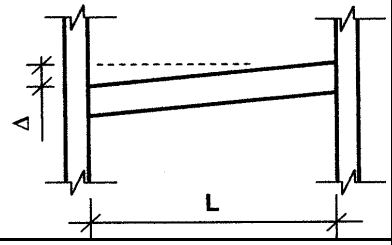
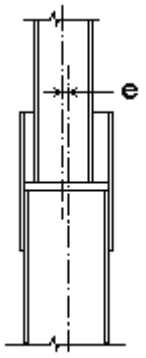
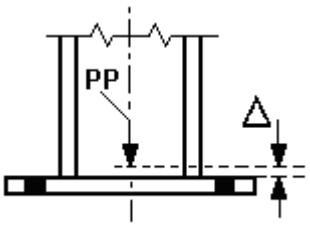
No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Inclination of single-storey columns generally: 	Overall inclination	$\Delta = \pm h/300$	$\Delta = \pm h/500$
2	Inclination of individual columns in single storey portal frame buildings: 	Inclination Δ of each column: $\Delta = \Delta_1$ or Δ_2	$\Delta = \pm h/150$	$\Delta = \pm h/300$
3	Inclination of single storey portal frame buildings: 	Mean inclination Δ of all the columns in the same frame: [For two columns: $\Delta = (\Delta_1 + \Delta_2)/2$]	$\Delta = \pm h/500$	$\Delta = \pm h/500$
4	Inclination of any column that supports a crane gantry: 	Inclination from floor level to bearing of crane beam:	$\Delta = \pm 25$ mm	$\Delta = \pm 15$ mm

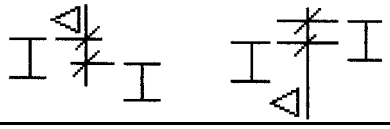
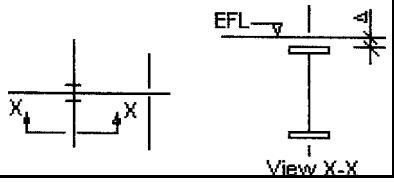
D.2.24 Functional erection tolerances – Multi-storey columns

No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Location at each storey level, relative to that at the base: 	Location of the column in plan, relative to a vertical line through its centre at base level	$\lvert\Delta\rvert = \Sigma h / (300\sqrt{n})$	$\lvert\Delta\rvert = \Sigma h / (500\sqrt{n})$
2	Inclination of a column, between adjacent storey levels: 	Location of the column in plan, relative to a vertical line through its centre at the next lower level	$\Delta = \pm h / 500$	$\Delta = \pm h / 1\,000$
3	Straightness of a continuous column between adjacent storey levels: 	Location of the column in plan, relative to a straight line between position points at adjacent storey levels	$\Delta = \pm h / 500$	$\Delta = \pm h / 1\,000$
4	Straightness of a spliced column, between adjacent storey levels: 	Location of the column in plan at the splice, relative to a straight line between position points at adjacent storey levels	$\Delta = \pm s / 500$ with $s \le h/2$	$\Delta = \pm s / 1\,000$ with $s \le h/2$

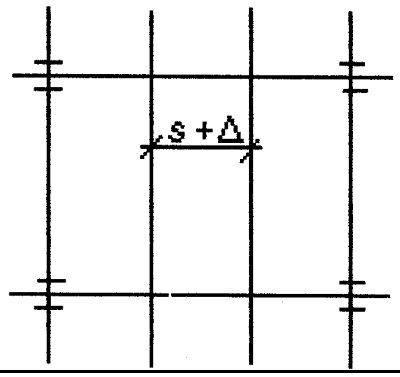
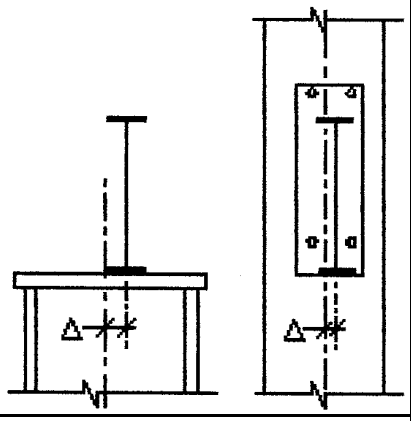
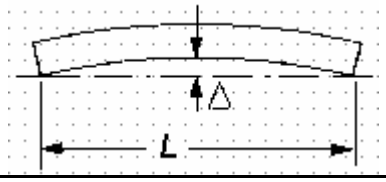
NOTE Table D.2.24 multi-storey columns applies to that are continuous over more than one storey.
Table D.2.23 single storey columns applies to storey-height columns in multi-storey buildings.

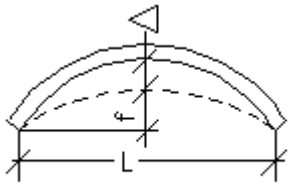
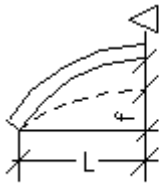
D.2.25 Functional erection tolerances – Buildings

No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Height: 	Overall height, relative to the base level: $h \leq 20$ m 20 m < h < 100 m $h \geq 100$ m	$\Delta = \pm 20$ mm $\Delta = \pm 0{,}5(h+20)$ mm $\Delta = \pm 0{,}2(h+200)$ mm [h in metres]	$\Delta = \pm 10$ mm $\Delta = \pm 0{,}25(h+20)$ mm $\Delta = \pm 0{,}1(h+200)$ mm [h in metres]
2	Storey height: 	Height relative to the adjacent levels	$\Delta = \pm 10$ mm	$\Delta = \pm 5$ mm
3	Slope: 	Height relative to the other end of a beam	$\Delta = \pm L/500$ but $\lvert\Delta\rvert \leq 10$ mm	$\Delta = \pm L/1000$ but $\lvert\Delta\rvert \leq 5$ mm
4	Column slice 	Non-intended eccentricity e (about either axis):	5 mm	3 mm
5	Column base: 	Level of bottom of column shaft, relative to specified level of its position point (PP)	$\Delta = \pm 5$ mm	$\Delta = \pm 5$ mm

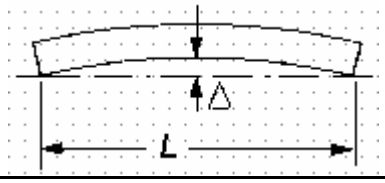
6	Relative levels: 	Levels of adjacent beams, measured at corresponding ends	$\Delta = \pm 10$ mm	$\Delta = \pm 5$ mm
7	Connection levels: 	Level of the beam at a beam-to-column connection, measured relative to the established floor level (EFL)	$\Delta = \pm 10$ mm	$\Delta = \pm 5$ mm
NOTE 1 The levels of beams should be measured relative to the established floor level [the best-fit to the specified floor levels, adjusted for tolerances in the column lengths]. NOTE 2 Notations such as $\Delta = \pm L/500$ but $\lvert\Delta\rvert \leq 5$ mm mean that the *smaller* of the two values is required.				

D.2.26 Functional erection tolerances – Beams in buildings

No	Criterion	Parameter	Permitted deviation Δ	
			Class 1	Class 2
1	Spacing: 	Deviation Δ from intended distance between adjacent erected beams, measured at each end	$\Delta = \pm 10$ mm	$\Delta = \pm 5$ mm
2	Location at columns: 	Deviation Δ from intended location of a beam-to-column connection, measured relative to the column	$\Delta = \pm 5$ mm	$\Delta = \pm 3$ mm
3	Straightness in plan: 	Deviation Δ from straightness of an erected beam or cantilever of length *L*	$\Delta = \pm L / 500$	$\Delta = \pm L / 1\,000$

4	Camber:  	Deviation Δ at mid span from intended camber *f* of an erected beam or lattice component of length *L*:	$\Delta = \pm L / 300$	$\Delta = \pm L / 500$
5	Pre-set of cantilevered part:  	Deviation Δ from intended pre-set at end of an erected cantilever of length *L*:	$\Delta = \pm L / 200$	$\Delta = \pm L / 300$

D.2.27 Functional erection tolerances - Roof sheeting designed as a stressed-skin

No	Criterion	Parameter	Permitted deviation Δ
1	Deviation of fixing (from the intended line of fixing: 1)  	Flange width of the purlin: *b*	$\Delta = \pm b / 10$ $\lvert\Delta\rvert \geq 5$ mm
2	Straightness of supporting purlin (in plane of roof sheeting):  	Span of the purlin*: L*	$\Delta = \pm L / 300$

D.2.28 Functional erection tolerances - Profiled steel sheeting

No	Criterion	Parameter	Permitted deviation Δ
1	Overall width of profiled sheeting:	Overall width *b* of profiled steel sheeting measured over a distance of 10 m	$\lvert\Delta\rvert \leq 200$ mm

Annex E
(informative)

Welded joints in hollow sections

E.1 General

This annex gives guidance for execution of welded joints in hollow sections.

E.2 Guidance for start and stop positions

The following guidance may be used for in-line joints:

a) stop and start positions of welds for in-line splice joints in chords should be chosen to avoid these positions coming directly under the location of a subsequent weld between a brace and the chord;

b) stop and start positions for welds between two in-line square or rectangular hollow sections should not be located at or close to the corner positions.

The following guidance may be used for other joints:

c) stop and start positions should not be located at or close to the toe position or lateral flank positions of a joint between two circular hollow sections in accordance with Figure E.1;

d) stop and start positions should not be located at or close to the corner positions of a joint between a square or rectangular hollow section bracing and a hollow chord component;

e) recommended welding sequence for welding brace to chord joints are given in Figure E.1;

f) welding between hollow sections should be completed all round, even if this total length of weld is not necessary for strength reasons.

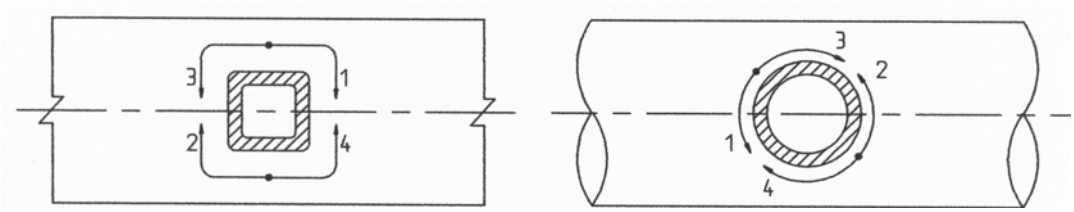


Figure E.1 — Start and stop positions and welding sequence

E.3 Preparation of joint faces

With reference to 7.5.1.2, examples of application of EN ISO 9692-1 to brace to chord joints between hollow sections are given in Figures E.2 to E.5).

Recommendations for the weld preparation and fit-up for mitre butt joints are locally the same as for butt welds between two components in-line, which requires the bevel angle to be increased on the inside of the mitre and reduced on the outside as shown in Figure E.6.

E.4 Assembly for welding

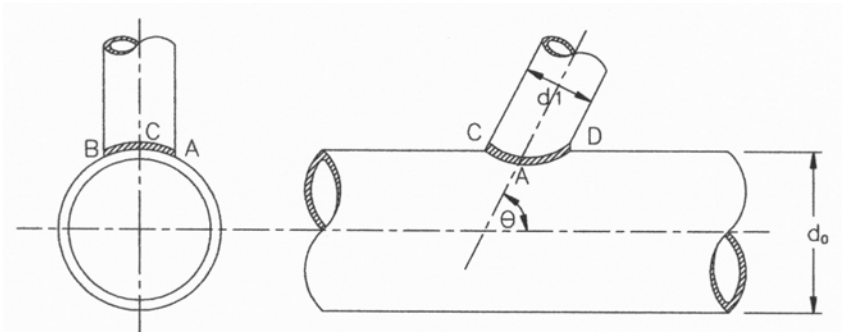
In accordance with 7.5.4 assembly of hollow section components to be welded shall be in accordance with the following requirements:

a) assembly using non-overlapping welding of the separate components is preferred (Case A in Figure E.7);

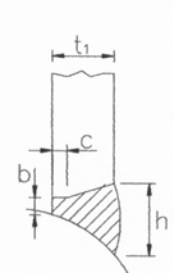
b) assembly of overlapping components should be avoided; if necessary Case B in Figure E.7 is acceptable;

c) if components overlap (as Case B), the welding details shall specified which components are to be cut to fit around other components;

d) the hidden toe area (as Case B) has not to be welded otherwise specified.



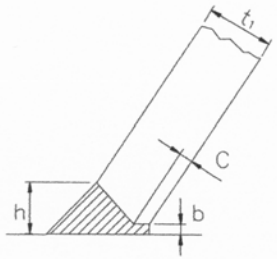
Detail at A, B:



where $d_1 < d_0$ $\theta = 60°$ to $90°$

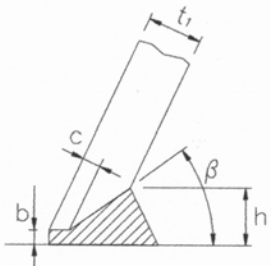
b = 2 mm to 4 mm
c = 1 mm to 2 mm

Detail at C:

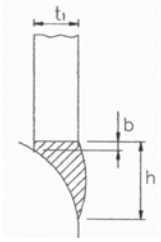


b = 2 mm to 4 mm
c = 1 mm to 2 mm

Detail at D:



b = 2 mm to 4 mm
c = 1 mm to 2 mm

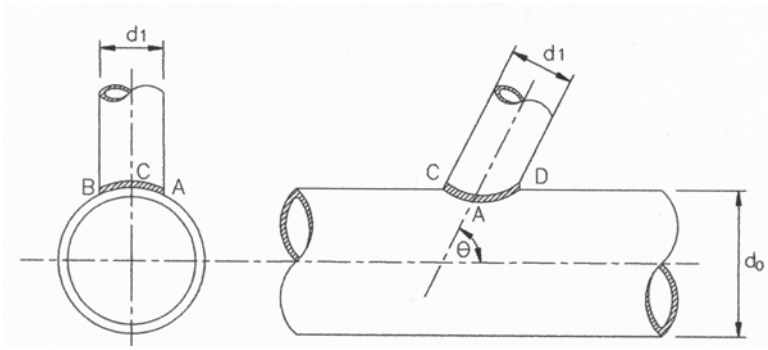


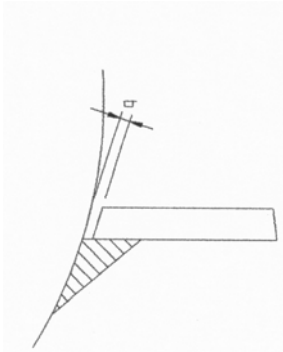
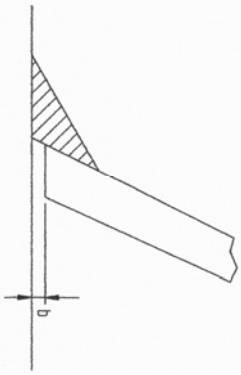
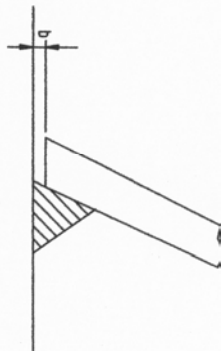
where $d_1 = d_0$
b = max. 2 mm

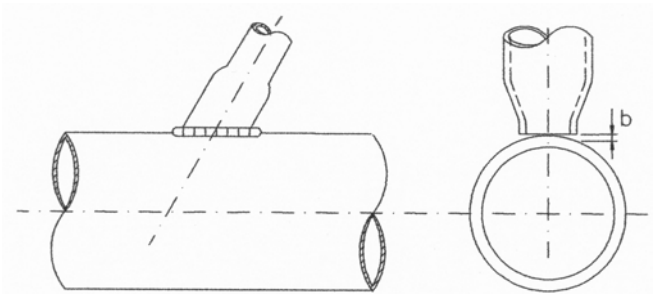
For $\theta < 60°$, a fillet weld detail (as Figure E.3)) should be used at D in the heel area.

NOTE Application of EN ISO 9692-1 case 1.4 to circular hollow sections.

Figure E.2 — Weld preparation and fit-up
Butt welds in circular hollow sections brace to chord joints

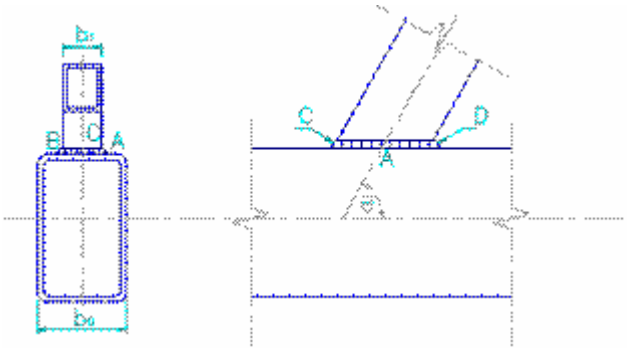


Detail at A, B:	Detail at C:	Detail at D:
		
	60° ≤ θ < 90°	30° ≤ θ < 90°
b = max. 2 mm	b = max. 2 mm	b = max. 2 mm
.	For θ < 60°, a butt weld detail (as Figure E.2)) should be used at C in the toe area	For the smaller angles, full penetration is not required provided there is adequate throat thickness

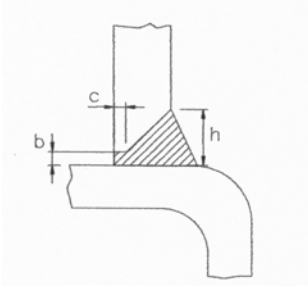


NOTE Application of EN ISO 9692-1 case 3.1.1 to circular hollow sections.

Figure E.3 — Weld preparation and fit-up
Fillet welds in circular hollow section brace to chord joints



Detail at A, B:

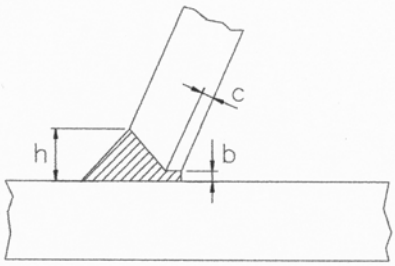


where $b_1 < b_0$

b = 2 mm to 4 mm

c = 1 mm to 2 mm

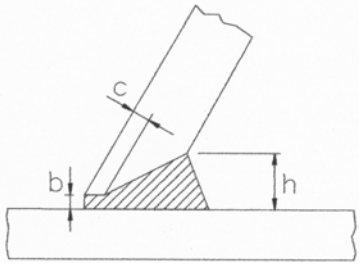
Detail at C:



b = 2 mm to 4 mm

c = 1 mm to 2 mm

Detail at D:

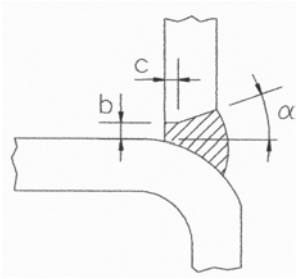


$60° \leq \theta < 90°$

b = 2 mm to 4 mm

c = 1 mm to 2 mm

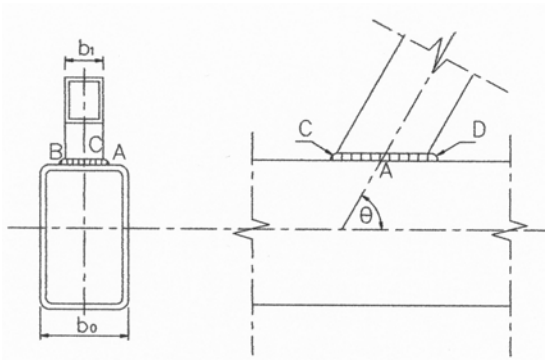
For $\theta < 60°$, a fillet weld detail (as Figure E.5)) is preferred to the detail at D in the heel area.



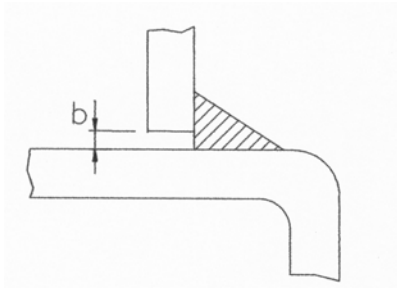
where $b_1 = b_0$
b = 2 mm max.
c = 1 mm to 2 mm
α = 20° to 25°

NOTE Application of EN ISO 9692-1 case 1.4 to square or rectangular hollow sections.

Figure E.4 — Weld preparation and fit-up
Butt welds in square or rectangular hollow section brace to chord joints

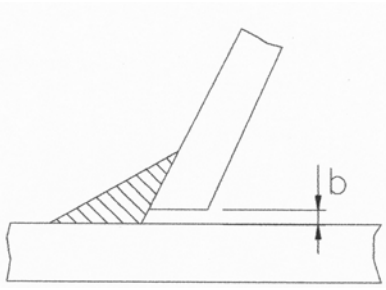


Detail at A,B:



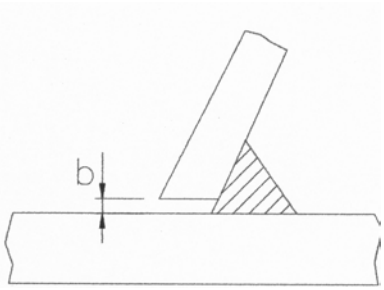
where $b_1 < b_0$
b = max. 2 mm

Detail at C:

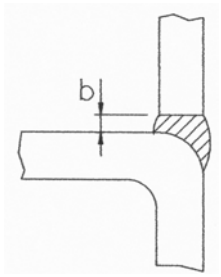


60° ≤ θ < 90°
b = max. 2 mm
For θ < 60°, a butt weld detail (as Figure E.4) should be used at C in the toe area.

Detail at D:



30° ≤ θ < 90°
b = max. 2 mm
For the smallest angles full penetration is not required provided there is adequate throat thickness



where $b_1 = b_0$
b = max. 2 mm

NOTE Application of EN ISO 9692-1 case 3.101 to square or rectangular hollow sections.

Figure E.5 — Weld preparation and fit-up
Fillet welds in square or rectangular hollow section brace to chord joints

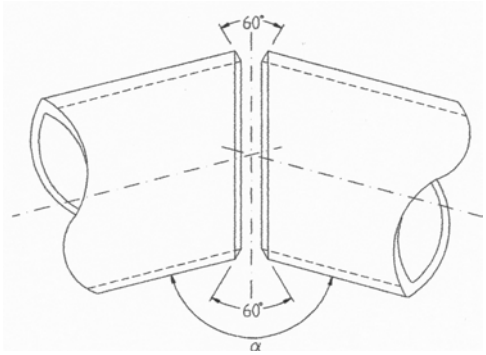
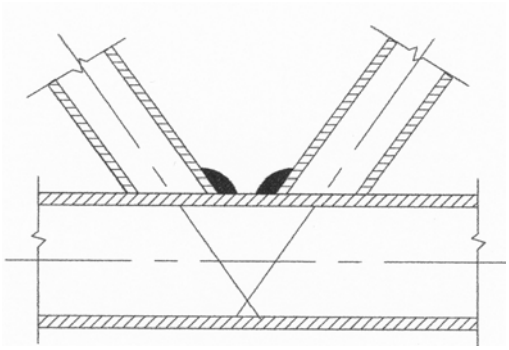


Figure E.6 — Weld preparation and fit-up for hollow section mitre joints

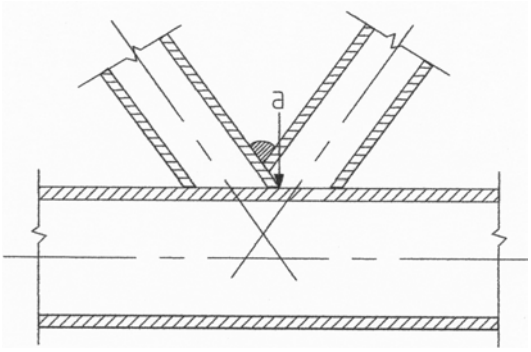


Separate components

Non-overlapping welds

PREFERRED DETAIL

Case A

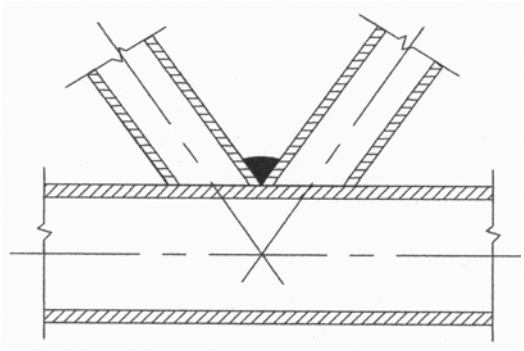


a = Hidden toe area does not need welding unless otherwise specified.

Overlapping components

ACCEPTABLE DETAIL

Case B



Separate components

but overlapping welds

DETAIL TO BE AVOIDED

Case C

Figure E.7 — Assembly of two brace components to a chord component

For joints not significantly subjected to dynamic loading, the following deviations may be permitted for the alignment between the root edges or root faces of in-line butt joints between hollow section components:

a) 25 % of the thickness of the thinner constituent product for material ≤12 mm thick;

b) 3 mm for material over 12 mm thick.

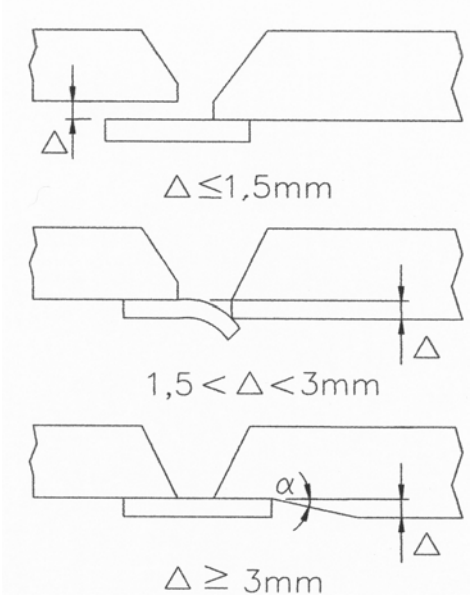
This alignment may be achieved using machining of ends to correct wall thickness variations and ovality or out-of-squareness of hollow sections, provided that the remaining material thickness complies with the minimum specified.

For in-line splice butt joints between hollow sections of different thickness, the thicknesses may be matched using the following guidance in accordance with Figure E.8:

a) if the difference in thickness does not exceed 1,5 mm, no special measures are necessary;

b) if the difference in thickness does not exceed 3 mm, the backing material may be shaped to accommodate the difference (local hot forming of the backing material may be used);

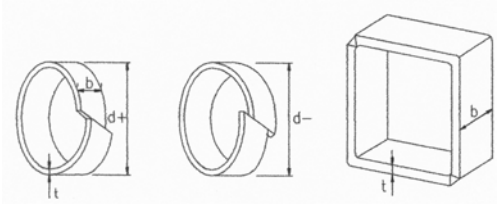
c) if the difference exceeds 3 mm the wall of the thicker component should be tapered with a slope of 1 in 4 or less.



The symbols Δ and α mean: Δ = thickness difference; tan α = slope, which shall not exceed 1 in 4.

Figure E.8 — Backing material details for components of different thickness

If it is not appropriate to use part of the steel structure as backing material, Figure E.9 gives guidance on suitable shapes for backing rings or strips.



Thickness t: 3-6 mm
Breadth b: 20-25 mm

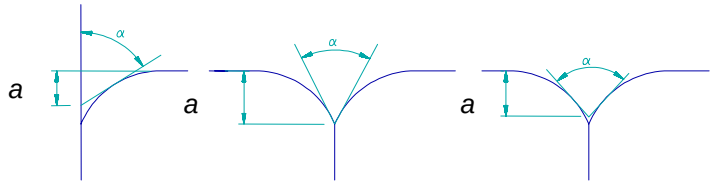
Figure E.9 —Suitable shapes for backing rings or strips

E.5 Fillet welded joints

For brace to chord joints , the welding procedure and the local profile of weld gap should be chosen to ensure a smooth transition between those parts of the weld that are butts (which should be in accordance with Figures E.2 and E.4 and those that are fillets (which should be in accordance with Figures E.3 and E.5).

For flare welds, the included angle of the weld preparation should exceed 60° for the effective depth of the weld, as shown in Figure E.10.

Here the symbol α means: Included angle 60°.



Determination of maximum effective depth of the weld, *a*,
without reinforcement based on included angle, α, of 60°.

Figure E.10 — Flare weld connecting two square/rectangular hollow section components

Annex F
(normative)

Corrosion protection

F.1 General

F.1.1 Field of application

This Annex gives requirements and guidelines relating to the execution of corrosion protection undertaken off-site and/or on-site on steel components with the exception of stainless steels. The field of application is corrosion protection by means of surface preparation and application of paint systems or metallic coatings by means of thermal spray or galvanizing. Cathodic protection is not included.

The requirements for corrosion protection shall be given in the execution specification in terms of a performance specification or as performance requirements for the protective treatment to be used.

NOTE 1 EN ISO 12944-8 gives guidelines for developing specifications for corrosion protection using paints.

This annex does not cover the corrosion protection of cables and fittings.

NOTE 2 See Annex A of EN 1993-1-11:2006.

F.1.2 Performance specification

The performance specification shall specify:

a) the expected life of the corrosion protection (see EN ISO 12944-1) and

b) the corrosivity category (see EN ISO 12944-2).

The performance specification may also state a preference for painting, thermal spraying or galvanizing.

F.1.3 Prescriptive requirements

If the expected life of a corrosion protection and corrosivity category are specified, prescriptive requirements shall be developed to comply with them. Otherwise, the execution specification shall define the prescriptive requirements giving details of the following items as are relevant:

a) surface preparation for manufactured steel components to be painted (see F.2.1);

b) surface preparation for manufactured steel components for thermal spraying (see EN 14616 and F.2.1);

c) surface preparation for manufactured steel components to be galvanized (see F.2.2);

d) processes for surface preparation of fasteners (see F.5);

e) paint system in accordance with EN ISO 12944-5 and/or paint products that have had their performance assessed according to EN ISO 12944-6. This may include requirements relevant to subsequent decorative coatings and restrictions on choice of colour for coating products;

f) work methods for initial application of paint products and repair (see EN ISO 12944-8 and F.6.1);

NOTE Repair on site of shop-applied coatings may require special consideration.

g) thermal spraying (see F.6.2);

h) galvanizing (see F.6.3);

i) particular requirements for inspection and checking (see F.7);

j) special requirements for bimetallic interfaces;

k) special requirements for sheetings.

F.1.4 Work method

Corrosion protection shall be undertaken in accordance with work methods that are based on a quality plan and that comply with F.2 to F.6 as relevant. The quality plan shall be developed from the prescriptive requirements in F.1.3.

Work methods shall identify whether work is to be undertaken pre- or post- manufacturing.

Corrosion protection products shall be used in accordance with the manufacturer's recommendations. Storage and handling procedures for materials shall ensure that the materials to be used are within their shelf life and pot life after opening or mixing.

All painted, thermal sprayed or hot dip galvanized products shall be carefully handled, stored and transported to avoid damage to their surfaces. Packing, wrapping and other materials used for handling and storage shall generally be of non-metallic type.

Adequate well-ventilated space, protected against the influence of weather, moisture and other coating work shall be provided to allow the paints to cure to an acceptable level and to avoid corrosion of metallic coatings.

No handling, storage and transport shall be performed before the coating system is cured to an acceptable level.

The curing time shall be not less than recommended by the product manufacturer.

Repair procedures shall be appropriate to the damage incurred using handling, storage and erection procedures.

F.2 Surface preparation of carbon steels

F.2.1 Surface preparation of carbon steels prior to painting and metal spraying

Surfaces shall be prepared in accordance with EN ISO 12944-4, and EN ISO 8501.

Procedure tests shall be undertaken on blast cleaning processes to establish the surface cleanliness and surface roughness achievable. These shall be repeated at intervals during production.

The results of procedure tests on blast cleaning processes shall be sufficient to establish that the process is suitable for the subsequent coating process.

Measurement and assessment of surface roughness shall be undertaken according to EN ISO 8503-1 and EN ISO 8503-2.

If coated materials are to receive further treatment, the surface preparation shall be appropriate to the subsequent treatment.

NOTE 1 Abrasive cleaning and wire brushing are not appropriate to sound metallic or organically coated components. However, if repairs to coatings are needed, it may be necessary to remove debris or corrosion deposits locally to reveal the basic steel substrate before carrying out the repair.

If overpainting of zinc coated steel is carried out, the cleaning of the surface requires particular attention. Surfaces shall be cleaned (removal of dust and grease) and possibly treated with a suitable etch primer or sweepblasting according to EN ISO 12944-4 to surface roughness “fine” in accordance with EN ISO 8503-2. The pre-treatment shall be checked before subsequent overcoating.

NOTE 2 Pre-coated galvanized steel strip is often supplied with a chromate passivation.

F.2.2 Surface preparation of carbon steels prior to galvanizing

Surfaces shall be prepared in accordance with EN ISO 8501 and EN ISO 1461 unless otherwise specified.

With pickling used prior to galvanizing, high strength steels may become susceptible to hydrogen-inducing cracking (see Annex C of EN ISO 1461:1999).

F.3 Welds and surfaces for welding

If a component is subsequently to be welded, the surfaces of the component within 150 mm of the weld shall not be coated with materials that will impair the quality of the weld (see also 7.5.1.1).

Welds and adjacent parent metal shall not be painted before de-slagging, cleaning, checking and acceptance of the weld (see also 10.2 - Table 22).

F.4 Surfaces in preloaded connections

For slip resistant connections, the execution specification shall specify requirements for friction surfaces and class of treatment or tests required (see 8.4 and 12.5.2.1).

For preloaded connections that are not required to be slip resistant, the extent of surfaces that are affected by the preloaded bolts shall be specified. If the contact surfaces are to be painted before assembly the dry coating thickness shall be between 100 µm and 75 µm. After assembly and preload, the connections shall be cleaned and finally painted with the relevant system.

F.5 Preparation of fasteners

The specification for the preparation of fasteners shall be consistent with the following:

a) the corrosion protection classification specified for the work or part of work;

b) the material and type of fastener;

c) the adjacent materials in contact with the fastener when in position and coatings on those materials;

d) the method of tightening the fastener;

e) the prospective need to repair the fastener treatment after tightening.

If preparation to fasteners is necessary after installation, it shall not be undertaken until the necessary inspection of the fastener has been completed.

The embedded part of foundation bolts shall be protected for at least the first 50 mm below the finished surface of the concrete. The remaining surfaces of the steel are to be left untreated unless otherwise specified (see EN ISO 12944-3).

F.6 Coating methods

F.6.1 Painting

The surface condition of the component shall be checked immediately prior to painting to ensure that it complies with the required specifications, EN ISO 12944-4, EN ISO 8501 and EN ISO 8503-2 and the manufacturer's recommendations for the product about to be applied.

Painting shall be undertaken in accordance with EN ISO 12944-7.

If two or more coats are to be applied, a different colour shade shall be used for each coat.

Structures with an expected life of the corrosion protection above 5 years with a C3 (and above) corrosivity category should have additional edge protection, by a stripe coat, extending across approximately 25 mm on both side of the edge and applied to a nominal thickness appropriate to the coating system.

Work shall not proceed if:

— the ambient temperature is below that recommended in the manufacturer's recommendations for the product to be applied;

— the surfaces to be coated are wet;

— the temperature of the surfaces to be coated is less than 3 °C above the dew point unless otherwise specified in the product datasheet.

Painted surfaces shall be protected against the accumulation of water for a period after application as required by the product data sheet.

The packing of painted components into bundles shall not commence until the paint manufacturer's declared hardening time has expired. Adequate well ventilated space, protected against the influence of weather, shall be provided to allow the coating to harden sufficiently. Appropriate measures shall be taken to prevent damage to the coating during packing and handling.

NOTE Cold formed components are often produced as nesting profiles. Tightly packing components into nested bundles before the paint treatment is sufficiently hardened may result in damage.

F.6.2 Metal spraying

Thermal metal spraying shall be of zinc, aluminium or zinc/aluminium 85/15 alloy and be undertaken in accordance with EN ISO 2063.

Thermal metal sprayed surfaces shall be treated with a suitable sealer before overcoating with paint in accordance with F.6.1. This sealer shall be compatible with the overcoating paint and shall be applied immediately after metal spraying cooling so as to avoid oxidation or moisture trapping.

F.6.3 Galvanizing

Galvanizing shall be undertaken in accordance with EN ISO 1461.

Galvanized surfaces of cold-formed components shall be provided by using precoated steel strip or by hot dip galvanizing after manufacturing.

NOTE 1 Coating masses, finishes and surface qualities are specified in EN 10326 and EN 10327.

If hot dip galvanizing after manufacturing is specified, it shall be undertaken in accordance with EN ISO 1461 and requirements for procedure qualification of the dipping process shall be specified.

NOTE 2 Light gauge cold-formed components often lack inherent stiffness. Long components composed of thin material can be susceptible to twisting due to stress relieving at the elevated temperature of the zinc bath.

Requirements for the inspection, checking or qualification of the preparation to be carried out before subsequent overcoating shall be specified.

F.7 Inspection and checking

F.7.1 General

Inspection and checking shall be undertaken in accordance with the quality plan and F.7.2 to F.7.4. The execution specification shall specify any requirements for additional inspection and testing.

Inspection and checking, including routine checking to F.7.2, shall be recorded.

F.7.2 Routine checking

Routine checking of corrosion protection shall comprise:

a) checks that prepared steel surfaces which are to receive corrosion protection treatment have the specified degree of cleanliness, assessment in accordance with EN ISO 8501 and the specified surface roughness, assessment in accordance with EN ISO 8503-2;

b) thickness measurement of:

   1) each layer of the paint coating in accordance with ISO 19840 and EN ISO 2808;

   2) thermal spraying in accordance with EN ISO 2063;

   3) galvanizing in accordance with EN ISO 1461.

   4) Visual inspection that paint treatment complies with the provisions of EN ISO 12944-7.

F.7.3 Reference areas

In accordance with EN ISO 12944-7, the execution specification shall define any reference areas to be used to establish the minimum acceptable standard for the work. Unless otherwise specified, reference areas shall be specified for corrosion protection systems in Corrosivity Categories C3 to C5 and Im1 to Im3.

F.7.4 Galvanized components

Unless otherwise specified, due to the risk of liquid metal assisted cracking (LMAC), galvanized components shall be subjected to post-galvanizing inspection.

NOTE Information on LMAC is given in [51].

The component specification shall specify the following:

a) components for which post-galvanizing inspection is not required;

b) components or specific locations that shall be subjected to additional NDT, the scope and method of which shall be specified.

The results of post-galvanizing inspection shall be recorded.

If evidence of cracking is identified, then the component and all similarly shaped components fabricated with similar materials and weld details shall be identified and quarantined as nonconforming products. A photographic record of the cracking shall be made and a specific procedure shall then be used to establish the scope and origin of the problem.

Annex G
(normative)

Test to determine slip factor

G.1 General

The purpose of this test is to determine the slip factor for a particular surface treatment, often involving a surface coating.

The test procedure is intended to ensure that account is taken of the possibility of creep deformation of the connection.

The validity of the test results for coated surfaces is limited to cases where all significant variables are similar to those of the test specimens.

G.2 Significant variables

The following variables shall be taken as significant on the test results:

a) the composition of the coating;

b) the surface treatment and treatment of primary layers in case of multi-layer systems, see G.3;

c) the maximum thickness of the coating, see G.3;

d) the curing procedure;

e) the minimum time interval between application of the coating and application of load to the connection;

f) the property class of the bolt, see G.6.

G.3 Test specimens

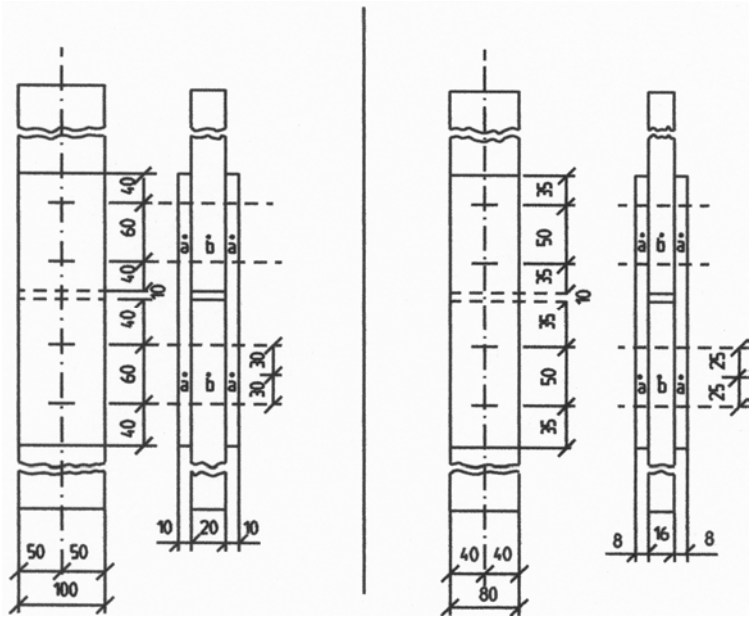
The test specimens shall conform to the dimensional details shown in Figure G.1.

The steel material shall conform to EN 10025-2 to -6.

To ensure that the two inner plates have the same thickness, they shall be produced by cutting them consecutively from the same piece of material and assembled in their original relative positions.

The plates shall have accurately cut edges that do not interfere with contact between the plate surfaces. They shall be sufficiently flat to permit the prepared surfaces to be in contact when the bolts have been preloaded in accordance with 8.1 and 8.5.

Dimensions in millimetres



a) M20 bolts in 22 mm dia holes b) M16 bolts in 18 mm dia holes

Figure G.1 — Standard test specimens for slip factor test

The specified surface treatment and coating shall be applied to the contact surfaces of the test specimens in a manner consistent with the intended structural application. The mean coating thickness on the contact surface of the test specimens shall be at least 25 % thicker than the nominal thickness specified for use in the structure.

The curing procedure shall be documented, either by reference to published recommendations or by description of the actual procedure.

The specimens shall be assembled such that the bolts are bearing in the opposite direction to the applied tension.

The time interval (in hours) between coating and testing shall be recorded.

The bolts shall be tightened to within ± 5 % of the specified preload, $F_{p,C}$, for the size and property class of the bolt used.

The preload in the bolts shall be directly measured with equipment that is accurate to ± 5 %.

NOTE If it is required to estimate bolt preload losses over time, the test specimens may be left for a specified period at the end of which the preloads may be again measured.

The bolt preloads in each test specimen shall be measured just prior to testing and, if necessary, the bolts shall be retightened to the required ± 5 % accuracy.

G.4 Slip test procedure and evaluation of results

Initially, five test specimens shall be tested. Four tests shall be loaded at normal speed (duration of test approximately 10 min to 15 min). The fifth test specimen shall be used for the creep test.

The specimens shall be tested in a tension loading machine. The load-slip relationship shall be recorded.

The slip shall be taken as the relative displacement between adjacent points on an inner plate and a cover plate, in the direction of the applied load. It shall be measured for each end of the specimen separately. For each end, the slip shall be taken as the mean of the displacements on both sides of the specimen.

The individual slip load for a connection, F_{Si}, is defined as the load at which a slip of 0,15 mm occurs.

The fifth test specimen shall be loaded with a specific load of 90 % of the mean slip load F_{Sm} from the first four specimens (i.e. the mean of eight values).

If for the fifth specimen the delayed slip, i.e. difference between the recorded slip at five minutes and at three hours after the application of the full load does not exceed 0,002 mm the slip loads for the fifth test specimen shall be determined as for the first four. If the delayed slip exceeds 0,002 mm extended creep tests shall be carried out in accordance with G.5.

If the standard deviation s_{Fs} of the ten values (obtained from the five test specimens) for the slip load exceeds 8 % of the mean value, additional specimens shall be tested. The total number of test specimens (including the first five) shall be determined from:

$n > (s/3,5)^2$

where

n is the number of test specimens;

s is the standard deviation s_{Fs} for the slip load from the first five specimens (ten values) expressed as a percentage of the mean slip load value.

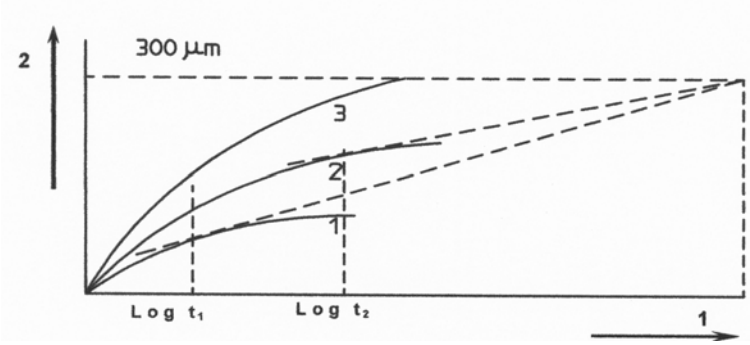
G.5 Extended creep test procedure and evaluation

If it is necessary to carry out extended creep tests, following G.4 at least three test specimens (six connections) shall be tested.

A specific load shall be applied to the test specimen whose value shall be determined so as to account both for the result of the creep test carried out in G.4 and for the results of all preceding extended creep tests.

NOTE A load corresponding to the slip factor proposed for use in the structural application may be adopted. If the surface treatment is to belong to a specified class, a load corresponding to the slip factor for that class may be taken in accordance with Table 18.

A “displacement - log time” curve shall be plotted (see Figure G.2) to demonstrate that the load determined using the proposed slip factor will not cause displacements greater than 0,3 mm during the design life of the structure, taken as 50 years unless otherwise specified. The “displacement - log time curve” may be extrapolated linearly as soon as the tangent can be determined with sufficient accuracy.



NOTE t_{Ld} Design life of structure

t_1 Minimum duration for test A

t_2 Minimum duration for test B

(3) The loading (slip factor) for test C is set too high

Key

1 log (time)

2 slip displacement

Figure G.2 — Use of the displacement - log time curve for extended creep test

G.6 Test results

Individual slip factor values are determined as follows:

$$\mu_i = \frac{F_{Si}}{4F_{p,C}}$$

The slip load mean value F_{Sm} and its standard deviation s_{F_S} are determined as follows:

$$F_{Sm} = \frac{\sum F_{Si}}{n}, \qquad s_{F_S} = \sqrt{\frac{(F_{Si} - F_{Sm})^2}{n-1}}$$

The slip factor mean value μ_m and its standard deviation s_μ are determined as follows:

$$\mu_m = \frac{\sum \mu_i}{n}, \qquad s_\mu = \sqrt{\frac{(\mu_i - \mu_m)^2}{n-1}}$$

The characteristic value of the slip factor μ shall be taken as the 5 % fractile value with a confidence level of 75 %.

For ten values, n = 10, from five specimens, the characteristic value may be taken as the mean value minus 2,05 times the standard deviation.

Unless extended creep testing is required, the nominal slip factor shall be taken equal to its characteristic value.

If extended creep testing is required, the nominal slip factor may be taken as the value demonstrated to satisfy the specified creep limit, see G.5.

Slip factors determined using bolts property class 10.9 may also be used for bolts property class 8.8.

Alternatively separate tests may be carried out for bolts property class 8.8. Slip factors determined using bolts property class 8.8 shall not be assumed valid for bolts property class 10.9.

If required, the surface treatment shall be assigned to the relevant friction surface class as follows, in accordance with the characteristic value of the slip factor μ determined in G4 or G5 as relevant:

$\mu \geq 0{,}50$	class A
$0{,}40 \leq \mu < 0{,}50$	class B
$0{,}30 \leq \mu < 0{,}40$	class C
$0{,}20 \leq \mu < 0{,}30$	class D

Annex H
(normative)

Test to determine torque values for preloaded bolts under site conditions

H.1 Scope

This Annex specifies a tightening test intended to represent site conditions to calibrate high-strength bolting assemblies for preloaded bolted connections.

The purpose of the test is to determine the necessary parameters to ensure that the minimum required preload is reliably obtained by the tightening methods specified in this European standard.

H.2 Symbols and units

A_s nominal stress area of the bolt, (mm^2) (see EN ISO 898-1)
e_M allowable ratio $(e_M = M_{max} - M_{min})/M_m$
F_b bolt force during the test, (kN)
$F_{p,C}$ required preload of 0,7 f_{ub} A_s, (kN)
f_{ub} nominal bolt strength (R_m), (MPa)
M_i individual value of the torque related to $F_{p,C}$, (N m)
M_m mean value of M_i values, (N m)
M_{max} maximum value of M_i values, (N m)
M_{min} minimum value of M_i values, (N m)
S_M estimated standard deviation of the M_i values
V_M coefficient of variation of the M_i values
θ_{pi} individual value of the angle θ at which the bolt force has first reached the value of $F_{p,C}$, (°)
θ_{1i} individual value of the angle θ at which the bolt force has reached its maximum value $F_{bi, max}$, (°)
θ_{2i} individual value of the angle θ at which the test is stopped, (°)
$\Delta\theta_{1i}$ the individual angle difference (θ_{1i} - θ_{pi}), (°)
$\Delta\theta_{2i}$ the individual angle difference (θ_{2i} - θ_{pi}), (°)
$\Delta\theta_{2\,min}$ the minimum required value of the angle difference $\Delta\theta_{2i}$ as specified in the relevant product standard (°)

H.3 Principle of the test

The principle of the test is to tighten assemblies and to measure, during tightening, the following parameters:

- the bolt force;
- the torque;
- the relative rotation between the nut and the bolt, if required.

H.4 Test apparatus

The bolt force measuring device may be in accordance with EN 14399-2, or a mechanical or hydraulic device such as a load cell, provided the accuracy of the bolt force measuring device meets the requirements given in Table H.1 or H.2 as relevant. The bolt force measuring device shall be calibrated at least once per year (or more frequently if recommended by the equipment manufacturer) by a recognized testing authority.

Torque wrenches to be used for the test shall be one of those to be used on site. They shall offer suitable operating range. Hand or power wrenches may be used, with exception of impact wrenches. The accuracy

requirements for the wrenches are given in Table H.1 or H.2 as relevant. The torque wrench shall be calibrated at least once per year (or more frequently if recommended by the manufacturer).

H.5 Test assemblies

Separate tests shall be carried out on representative samples from each lot of fastener assemblies concerned. Test assemblies shall be chosen so that all relevant aspects of their conditions are similar.

NOTE The site conditions of fasteners, in particular the performance of the lubrication, can vary if they are left exposed to extreme environmental conditions on site or if they are stored for a long period of time.

Representative assemblies shall consist of a number of bolts, nuts and washers of each inspection lot. The assemblies used for tests shall not be re-used for supplementary tests or in the structure.

H.6 Test set up

The test set-up (see Figure H.1) may include shims needed to suit the measuring device.

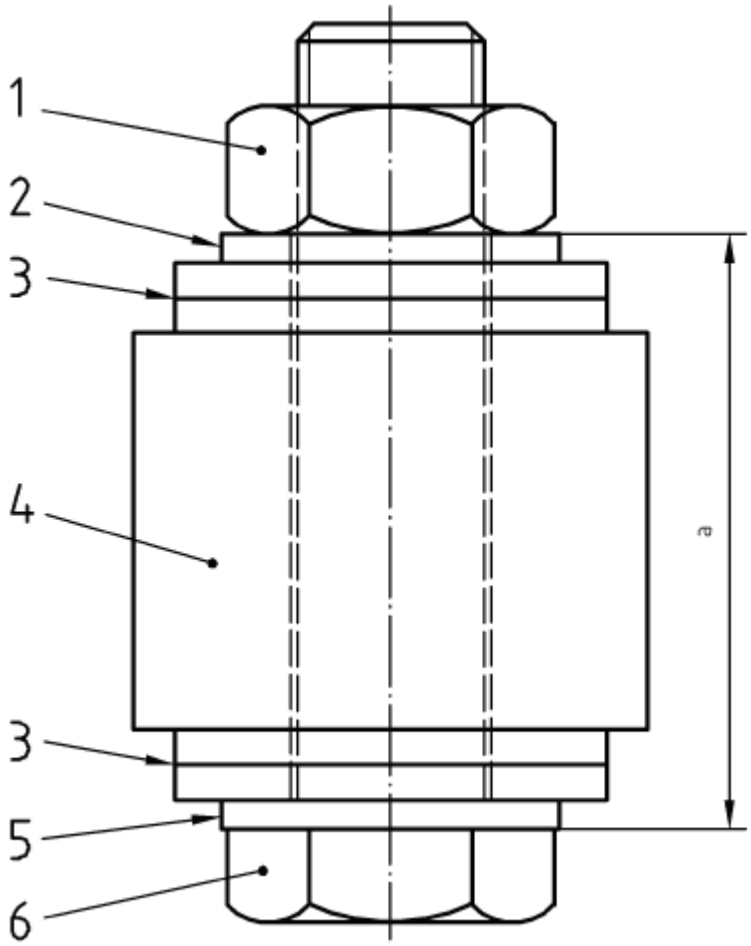
The test assemblies and shims shall be positioned such that:

— the composition of the assembly is similar to the utilisation in practice;

— a chamfered washer or a chamfered shim is placed under the bolt head;

— a washer is placed under the nut when the nut will be turned during tightening;

— the clamp length including the shims and washer(s) is the minimum allowed in the relevant product standard.



Key

1 nut
2 washer under the nut when nut turned during tightening
3 shim(s)
4 bolt tension measuring device
5 chamfered washer of the assembly or chamfered shim
6 bolt head

Figure H.1 — Typical assembly of the tension measuring device

H.7 Test procedure

For site tests the method used for tightening during the test shall be the same as that used on the site. For site tests the basis of calibration is to record the torque values M_i needed to achieve the target preload tension in the bolt.

Tests may be carried out either in a laboratory or elsewhere under suitable conditions. The method used for tightening shall be the same as that to be used on the site.

NOTE In certain cases it may be more convenient to have the product manufacturer check whether fastener assemblies still meet the declared as-delivered properties.

Sufficient measurements shall be taken of the torque, the corresponding bolt tension and, if required, the corresponding rotation of the turned part so as to permit the evaluation of the test results in accordance with H.8.

Neither the fixed part nor the washer under the turned part shall rotate during the test.

The basis of calibration is to record the torque values M_i needed to achieve the bolt force $F_b = F_{p,C} = 0,7\ f_{ub}\ A$s.

The test shall be terminated when any one of the following conditions is satisfied:

— the bolt force exceeds 1,1 $F_{p,C}$;

— the angle of nut rotation exceeds ($\theta_{pi} + \Delta\theta_1$) and/or ($\theta_{pi} + \Delta\theta_{2\,min}$), if required;

— bolt failure by fracture occurs.

H.8 Evaluation of test results

The criteria for acceptance of the torque values for the combined method and for the torque method are given in Tables H.1 and H.2 respectiveley.

Table H.1 — Maximum values for e_M for the combined method

Number of tests	**3**	**4**	**5**	**6**
$e_M = (M_{max} - M_{min}) / M_m$	0,25	0,30	0,35	0,40
Required test equipment conditions: calibrated bolt tension device uncertainty ± 6 %, repeatability error ± 3 %, calibrated torque wrench accuracy ± 4 %, repeatability error ± 2 %.				

Table H.2 — Maximum values for V_M for torque method

Number of tests	**5**	**6**	**8**
V_M	0,04	0,05	0,06
Required test equipment conditions: calibrated bolt tension device uncertainty ± 2 %, repeatability error ± 1 %, calibrated torque wrench accuracy ± 4 %, repeatability error ± 1 %.			

With:

$$M_m = \frac{\sum_{i=1}^{n} M_i}{n} \qquad s_M = \sqrt{\frac{\sum (M_i - M_m)^2}{n-1}} \qquad V_M = \frac{s_m}{M_M}$$

If required to be checked, the acceptance criteria for the rotations $\Delta\theta_1$ and $\Delta\theta_2$ shall be those in the relevant Part of EN 14399 for the fasteners in the assembly lot.

NOTE The rotations $\Delta\theta_1$ and $\Delta\theta_2$ are shown in Figure 2 of EN 14399-2:2005.

If the rotations are checked, then the maximum tension in the bolt shall be measured (i.e. that force corresponding to the rotation $\Delta\theta_1$). The requirement is that the maximum tension shall be equal to or greater than 0,9 $f_{ub}\ A_s$ with f_{ub} and A_s based on nominal values.

H.9 Test report

The following minimum information shall be included in the test report:

— date of testing;

— identification number of the assembly lot or the extended assembly lot;

— number of assemblies tested;

— designation of the fasteners;

— marking of bolts, nuts and washers;

— coating or surface finish and lubrication condition; if relevant, description of alterations to the surfaces due to site exposure;

— test clamp length;

— details of the test set-up and devices used to measure tension and torque;

— remarks concerning the execution of tests (including special testing conditions and procedures such as turning the head of the bolt);

— tests results according to this annex;

— specifications for the preloading of the fasteners related to the inspection lot tested.

The test report shall be signed and dated.

Annex J
(normative)

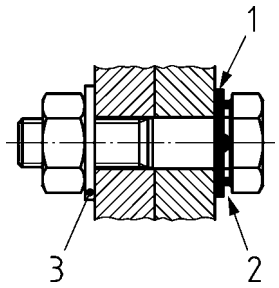
Use of compressible washer-type direct tension indicators

J.1 General

This annex gives requirements for the fitting and checking of compressible washer-type direct tension indicators.

J.2 Fitting

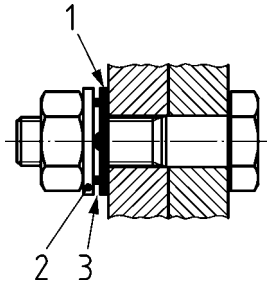
Indicators are generally fitted under the bolt head and the bolt is generally tightened by rotation of the nut, as shown in Figure J.1 a). Limited access to the bolt head for the purposes of inspecting the indicator gap may require the indicator to be fitted under the nut. If used in this manner the appropriate nut face washer is fitted between the indicator protrusions and the nut (see Figure H 1 b)).



Key
1 indicator
2 gap
3 nut face washer

NOTE For 10.9 bolt applications a chamfered washer is needed under the bolt head.

a) under bolt head fitting, before tightening



Key
1 indicator
2 nut face washer
3 gap

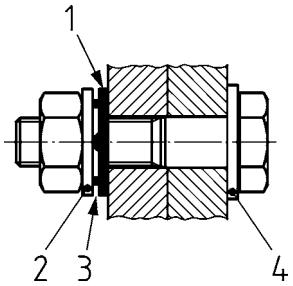
NOTE For 10.9 bolt applications a chamfered washer is needed under the bolt head.

b) under nut fitting, before tightening

Figure J.1 — Bolt tightening by rotation of the nut (normal method of assembly)

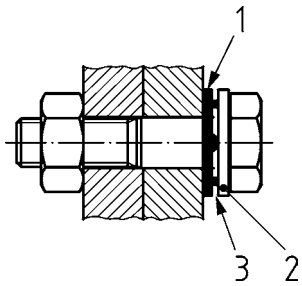
Conditions of limited access may require the bolt to be tightened by rotation of the bolt head. In this case a nut face washer is fitted between the indicator protrusions and the bearing surface of the nut as shown in Figure J.2 a).

If there is limited space for positioning of the bolt, combined with limited access for inspection of the indicator gap, it may be necessary to fit the indicator under the bolt head and to tighten the assembly by rotation of the bolt head. In this case a bolt face washer is fitted between the indicator protrusions and the bearing surface of the nut (see Figure J.2b).



Key
1 indicator washer
2 nut face washer
3 gap
4 through hardened

a) under nut fitting, before tightening



Key
1 indicator washer
2 bolt face washer
3 gap

NOTE For 10.9 bolt applications a plain washer is needed under the nut.

b) under bolt head fitting, before tightening

Figure J.2 — Bolt tightening by rotation of the bolt (alternative method of assembly)

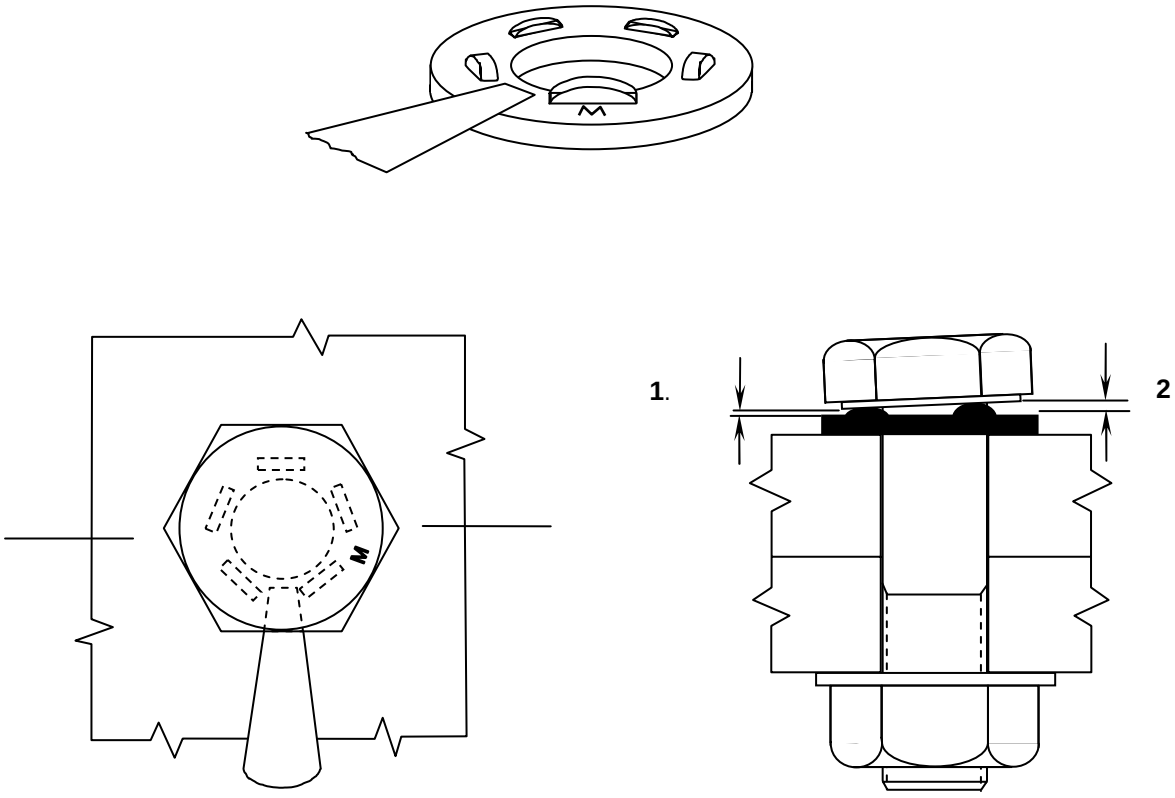
J.3 Checking

A feeler gauge as specified in Table J.1 shall be used to determine whether the direct tension indicator has compressed in accordance with the requirements of prEN 14399-9.

Table J.1 — Thickness of feeler gauge

Indicator positions	Thickness of feeler gauge (a) (mm)
Under bolt head, when nut is rotated (Figure J.1 a))	0,40
Under nut, when bolt is rotated (Figure J.2 a))	
Under nut, when nut is rotated (Figure J.1 b))	0,25
Under bolt head, when bolt is rotated (Figure J.2 b))	
(a) This table applies to both H8 and H10 DTIs	

The indicator gap shall be checked using the feeler gauge as a “no go” inspection tool. The feeler gauge shall be pointed at the centre of the bolt as shown in Figure J.3.



Key
1 “No go” gap if refusal occurs
2 “Go” gap if refusal does not occur

Figure J.3 — Checking the indicator gap

The indicator has been compressed sufficiently when the number of feeler gauge refusals meets the requirement given in Table J.2.

Table J.2 — Feeler gauge refusals

Number of indicator protrusions	Minimum number of feeler gauge refusals [a]
4	3
5	3
6	4
7	4
8	5
9	5

[a] No more than 10 % of the indicators in a connection bolt group shall exhibit full compression of the indicator.

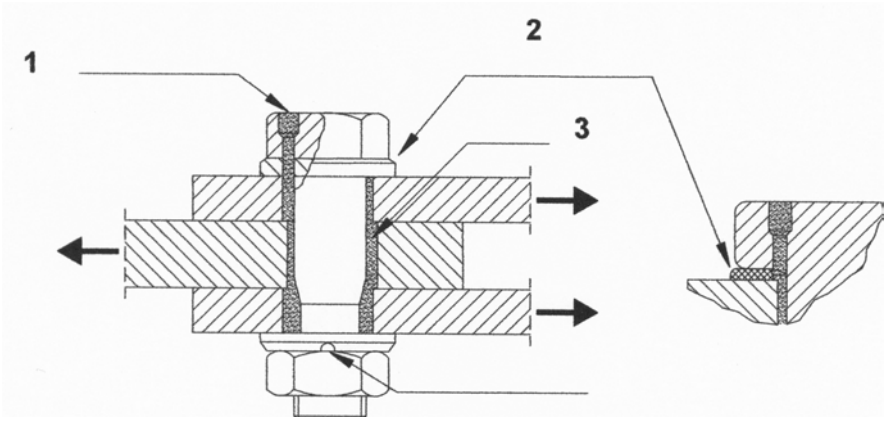
Annex K
(informative)

Hexagon injection bolts

K.1 General

This annex provides information on the supply and use of hexagon injection bolts.

Injection bolts may be used as non-preloaded or preloaded bolts, as specified. Filling of the clearance between the bolt and the inside surface of the hole is carried out through a small hole in the head of the bolt as shown in Figure K.1. After injection and complete curing of the resin, the connection is slip resistant.



Key
1 injection hole
2 chamfered washer
3 resin
4 air escape groove in the washer

Figure K.1 — Injection bolt in a double lap joint

Injection bolts should be made of materials in accordance with Clause 5 and used in accordance with Clause 8 supplemented by the recommendations in this annex.

NOTE Detailed information is given in [50].

K.2 Hole sizes

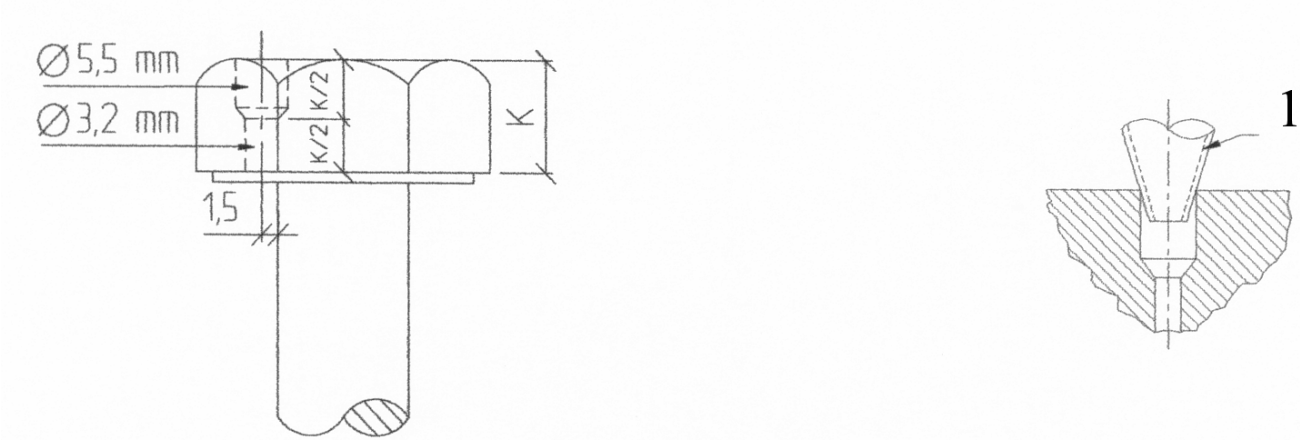
The nominal clearance for bolts in the hole should be 3 mm. For bolts smaller than M27 the clearance may be reduced to the clearance of 2 mm, as specified in 6.6 for normal round holes.

K.3 Bolts

The head of the bolt should be provided with a hole having a position and dimensions as specified in Figure K.2.

If other types of nozzle than plastic nozzles are used, the edge may need to be chamfered in order to guarantee sufficient sealing.

Dimensions in millimetres



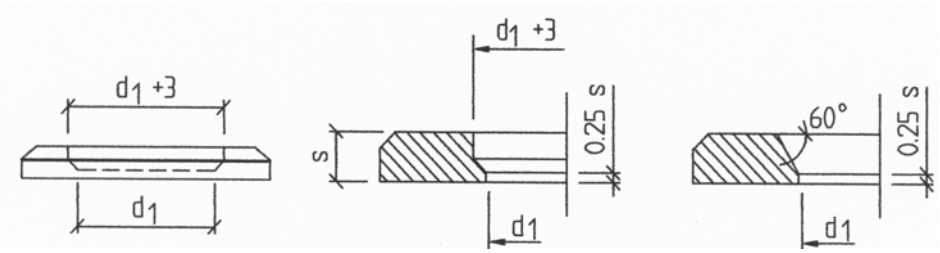
Key

1 nozzle of injection device

Figure K.2 — Hole in the head of the bolt

K.4 Washers

Under the bolt head a special washer should be used. The inner diameter of this washer should be at least 0,5 mm larger than the actual diameter of the bolt. One side should be machined according to Figure K.3 a) or K.3 b).



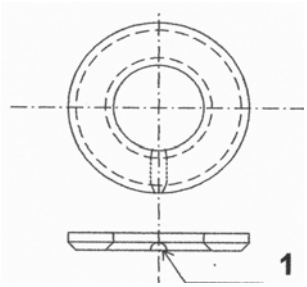
a) Drilled b) Chamfered

Figure K.3 — Preparation of the washer for use under the bolt head

The washer under the bolt head should be positioned with the rebate towards the bolt head.

Under the nut a special washer provided with a groove according to Figure K.4 should be used. The edges of the groove should be smooth and rounded.

The washer under the nut should be positioned with the groove towards the nut.



Key

1 groove

Figure K.4 — Preparation of the washer for use under the nut

K.5 Nuts

The nuts may be assumed to be sufficiently secured by the resin.

K.6 Resin

A two component resin should be used.

After the mixing of the two components, the mass should have such a viscosity, at the ambient temperature during installation, that the narrow spaces in the bolted connection will be filled easily. However, the flowing of the mass should stop after the injection pressure has been removed.

The potlife of the resin should be at least 15 min at the ambient temperature.

If there are no data available, procedure tests should be carried out to determine the appropriate temperature and curing time.

The design bearing strength of the resin should be determined similar to the procedure for the determination of the slip factor as specified in Annex G.

K.7 Tightening

Tightening of the bolts in accordance with Clause 8 should be carried out before starting the injection procedure.

K.8 Installation

The installation should be carried out in accordance with the recommendations given by the product manufacturer.

The temperature of the resin should be between 15 °C and 25 °C. In very cold weather the resin and if necessary the steel components should be preheated. If the temperature is too high, modelling clay may be used to close the hole in the head and the groove in the washer immediately after injection.

The connection should be free from water at the time of injection.

NOTE 1 To get rid of the water one day of dry weather is generally necessary before starting the injection procedure.

The curing time should be such that the resin is cured before the structure is loaded.

Heating after injection is permitted in order to reduce the curing time, if necessary.

NOTE 2 In some cases e.g. the repair of railway bridges, this time can be rather short. To reduce the curing time (to about 5 h) the connection may be heated to a maximum of 50 °C after the potlife has passed.

Annex L
(informative)

Guide to flow diagram for development and use of a WPS

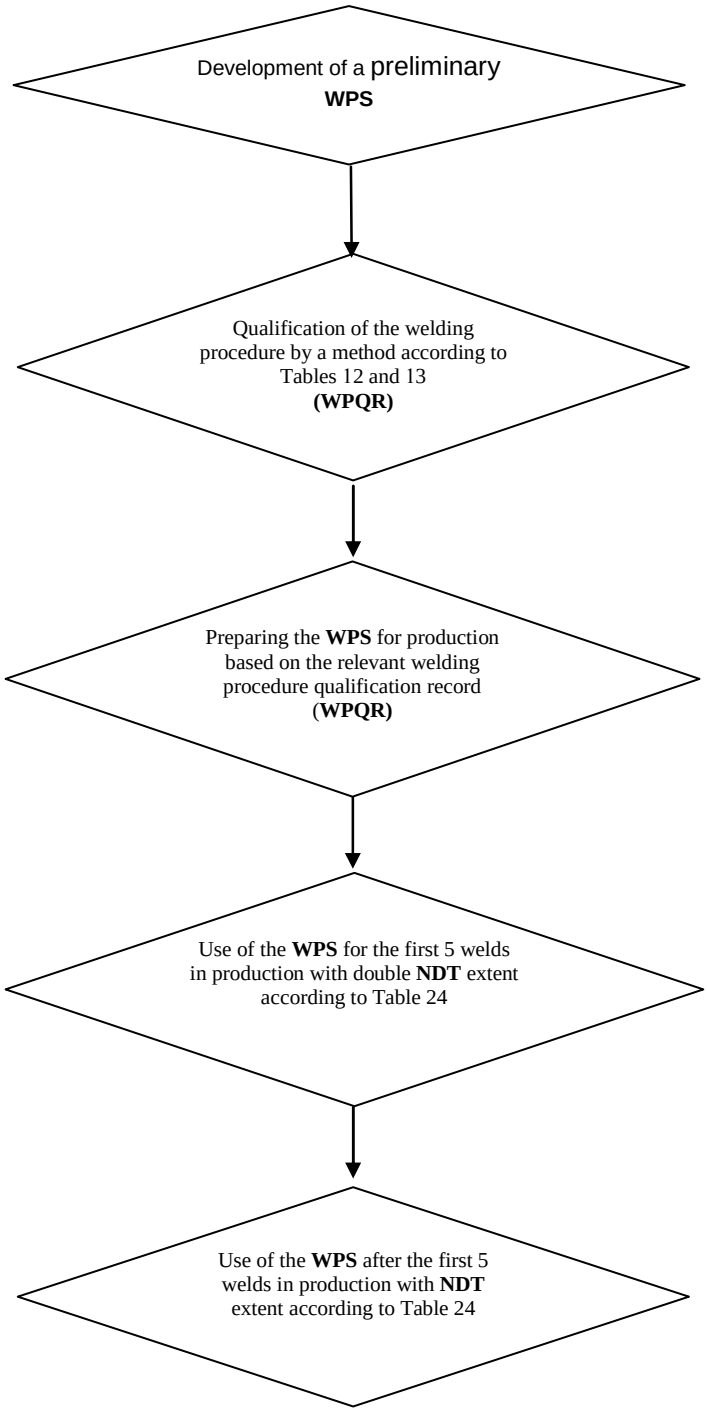


Figure L.1 — Flow diagram for development and use of a WPS

Annex M
(normative)

Sequential method for fasteners inspection

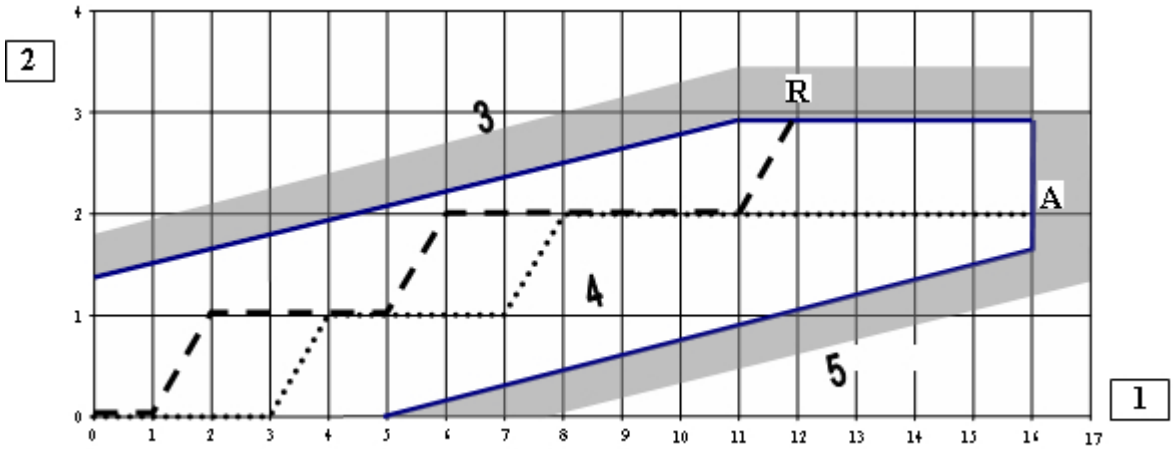
M.1 General

The sequential method for fasteners inspection shall be carried out according to the principles in ISO 2859-5, the purpose of which being to give rules based on progressive determination of inspection results.

ISO 2859-5 gives two methods for establishing sequential sampling plans: numerical method and graphic method. The graphic method is applied for fasteners inspection.

In the graphic method (see Figure M.1) the horizontal axis is the number of fasteners inspected and the vertical axis the number of defective fasteners.

The lines on the graph define three zones: the acceptance zone, the rejection zone and the indecision zone. As long as the inspection result is in the indecision zone the inspection is continued until the cumulative plot emerges into either the acceptance zone or the rejection zone. Acceptance means that no further sample inspection is required. Two examples are given below.



Key
1 number of fasteners inspected
2 number of defective fasteners
3 rejection zone
4 indecision zone
5 acceptance zone

Figure M.1 — Example of sequential inspection diagram

EXAMPLES

Dotted line The 4th and 8th fasteners were found defective. Inspection was continued until crossing the vertical curtailment line. The result is ”acceptance”.

Dashed line The 2nd, 6th and 12th fasteners were found defective. Exit from the indecision zone is into the rejection zone. The result is ”rejection”.

M.2 Application

The following diagrams, M.2 (sequential type A) and M.3 (sequential type B) apply as relevant.

a) Sequential type A:

1) minimum number of fasteners to be inspected: 5

2) maximum number of fasteners to be inspected: 16

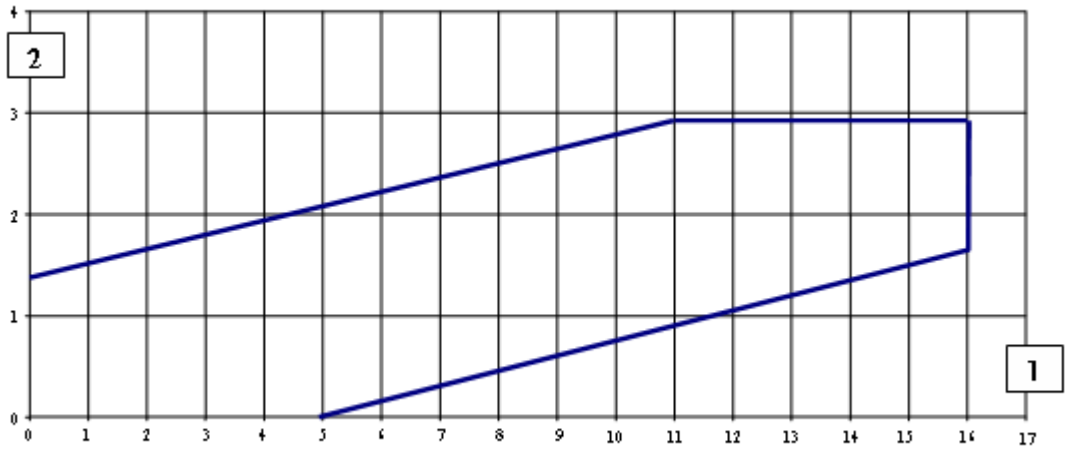


Figure M.2 — Sequential type A diagram

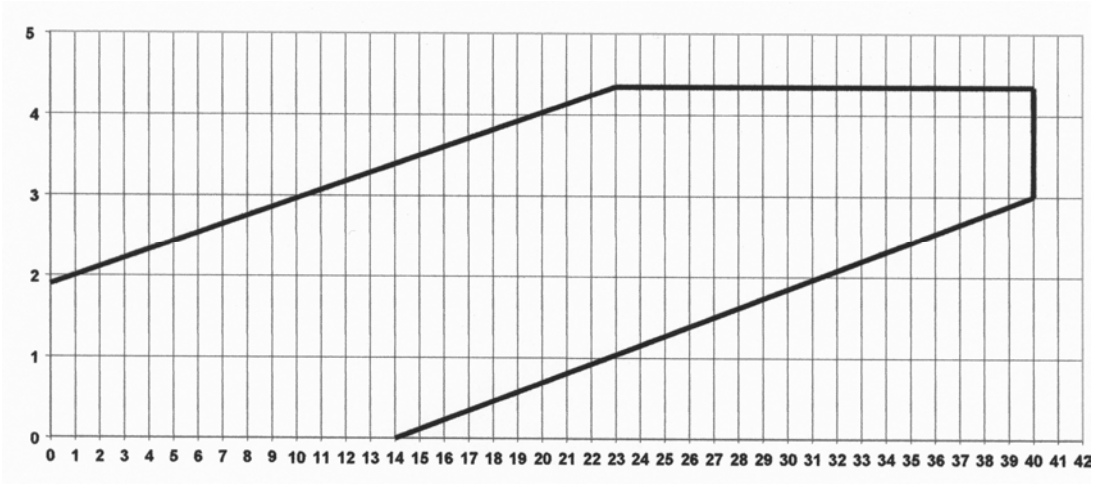
Key
1 number of fasteners inspected
2 number of defective fasteners

b) Sequential type B:

1) minimum number of fasteners to be inspected: 14

2) maximum number of fasteners to be inspected: 40

1



2

Key
1 number of fasteners inspected
2 number of defective fasteners

Figure M.3 — Sequential type B diagram

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