BS EN 1090-2:2018

BSI Standards Publication

Execution of steel structures and aluminium structures

Part 2: Technical requirements for steel structures

bsi.

National foreword

This British Standard is the UK implementation of EN 1090-2:2018. It supersedes BS EN 1090-2:2008+A1:2011, which is withdrawn.

BSI, as a member of CEN, is obliged to publish EN 1090-2:2018 as a British Standard. However, attention is drawn to the fact that during the development of this European Standard, the UK committee decided to abstain from voting to approve it as a European Standard because it was unable to reach a consensus position.

The UK committee has concerns over the lack of clarity between the scope of BS EN 1090-2:2018 and the scope of the new BS EN 1090-4, particularly regarding product forms, material grades, thickness limits and joining processes.

Another concern with EN 1090-2:2018 is its relationship with both BS EN 1990:2002+A1:2005 and the design rules in the BS EN 1993 series, particularly about reliability differentiation and the integrity of welded joints. Although EN 1090-2:2018 contains sufficient choices to ensure full compatibility with these standards, care must be taken to ensure the correct choices are made. Further information on these choices is given in Clause NA.2.27.3 of the National Annex to BS EN 1993-1-1:2005+A1:2014.

The UK participation in its preparation was entrusted to Technical Committee CB/203, Design & execution of steel structures.

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

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

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

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Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1090-2

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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 22 January 2018.

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-CENELEC 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-CENELEC Management Centre has the same status as the official versions.

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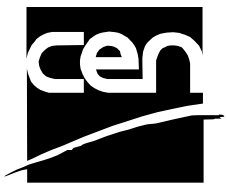

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN 1090-2:2018) 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 December 2018 and conflicting national standards shall be withdrawn at the latest by December 2018.

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

This document supersedes EN 1090-2:2008+A1:2011.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document is part of the EN 1090 series, which comprises the following parts:

— EN 1090-1, *Execution of steel structures and aluminium structures - Part 1: Assessment and verification of constancy of performance for structural components*

— EN 1090-2, *Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures*

— EN 1090-3, *Execution of steel structures and aluminium structures - Part 3: Technical requirements for aluminium structures*

— EN 1090-4, *Execution of steel structures and aluminium structures - Part 4: Technical requirements for cold-formed structural steel elements and cold-formed structures for roof, ceiling, floor and wall applications*

— EN 1090-5, *Execution of steel structures and aluminium structures - Part 5: Technical requirements for cold-formed structural aluminium elements and cold-formed structures for roof, ceiling, floor and wall applications*

Technical requirements for cold-formed structural steel elements, members and sheeting and cold-formed steel structures for roof, ceiling, floor, wall, and cladding applications have been removed from this Part of the EN 1090 series, as they are given in EN 1090-4.

Informative Annex B giving guidance for the determination of execution class has been removed as normative requirements for the selection of execution class are now included in of EN 1993-1-1:2005/A1:2014, Annex C.

A new informative Annex D has been included giving guidance on a procedure for checking the capability of thermal cutting processes.

A new informative Annex I has been included giving guidance on determination of the loss of preload from thick coatings on contact surfaces in preloaded connections.

Normative Annex J “Use of compressible washer-type direct tension indicators” has been removed.

A new informative Annex L has been included giving guidance on the selection of weld inspection classes.

Other annexes have been renumbered accordingly:

— Annex D becomes Annex B;

— Annex K becomes Annex J;

— Annex L becomes Annex K.

Annexes A, C, E, F, G, H and M have not been renumbered.

There have been some amendments included in these annexes.

The main text contains some changes. It includes updated cross-references to supporting standards and some corrections.

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, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey 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 the EN 1993 series and the steel parts of composite steel and concrete structures designed according to the EN 1994 series.

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 S700;

— cold formed components and sheeting up to and including grade S700 (unless coming within the scope of EN 1090-4);

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

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

For components produced from cold formed components, and cold formed structural hollow sections that are within the scope of EN 1090-4, the requirements of EN 1090-4 take precedence over corresponding requirements in this European Standard.

This European Standard can 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, which are mostly 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. Certain requirements are differentiated in terms of execution classes.

This European Standard applies to structures designed according to the relevant part of the EN 1993 series. Sheet piling, displacement piles and micropiles designed to EN 1993-5 are intended to be executed in accordance with respectively EN 12063, EN 12699 and EN 14199. This European Standard only applies to the execution of waling, bracing, and connections.

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

This European Standard can 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 includes the requirements for the welding of reinforcing steels to structural steels. This European Standard does not include requirements for the use of reinforcing steels for reinforced concrete applications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

2.1 Constituent products

2.1.1 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, *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 and shape*

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

EN 10048, *Hot rolled narrow steel strip - Tolerances on dimensions and shape*

EN 10051, *Continuously hot-rolled strip and plate/sheet cut from wide 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 purposes - 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 10088-4:2009, *Stainless steels - Part 4: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for construction purposes*

EN 10088-5:2009, *Stainless steels - Part 5: Technical delivery conditions for bars, rods, wire, sections and bright products of corrosion resisting steels for construction 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 low carbon 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 (all parts), *Hot rolled flat products made of high yield strength steels for cold forming*

EN 10163 (all parts), *Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections*

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

EN 10169, *Continuously organic coated (coil coated) steel flat products — Technical delivery conditions*

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, dimensions 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 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 10346, *Continuously hot-dip coated steel flat products for cold forming - Technical delivery conditions*

EN 10365, *Hot rolled steel channels, I and H sections - Dimensions and masses*

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

EN ISO 9444-2, *Continuously hot-rolled stainless steel - Tolerances on dimensions and form - Part 2: Wide strip and sheet/plate (ISO 9444-2)*

EN ISO 9445 (all parts), *Continuously cold-rolled stainless steel - Tolerances on dimensions and form - Part 1: Narrow strip and cut lengths (ISO 9445 series)*

EN ISO 18286, *Hot-rolled stainless steel plates - Tolerances on dimensions and shape (ISO 18286)*

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

2.1.2 Steel castings

EN 1559-1, *Founding - Technical conditions of delivery - Part 1: General*

EN 1559-2, *Founding - Technical conditions of delivery - Part 2: Additional requirements for steel castings*

EN 10340, *Steel castings for structural uses*

2.1.3 Welding consumables

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

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

EN ISO 3581, *Welding consumables - Covered electrodes for manual metal arc welding of stainless and heat-resisting steels - Classification (ISO 3581)*

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

EN ISO 14171, *Welding consumables - Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels - Classification (ISO 14171)*

EN ISO 14174, *Welding consumables - Fluxes for submerged arc welding and electroslag welding - Classification (ISO 14174)*

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

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

EN ISO 14343, *Welding consumables - Wire electrodes, strip electrodes, wires and rods for arc welding of stainless and heat resisting steels - Classification (ISO 14343)*

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

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)*

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)*

EN ISO 18275, *Welding consumables - Covered electrodes for manual metal arc welding of high-strength steels - Classification (ISO 18275)*

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)*

EN ISO 26304, *Welding consumables - Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels - Classification (ISO 26304)*

2.1.4 Mechanical fasteners

EN 14399 (all parts), *High-strength structural bolting assemblies for*

EN 15048 (all parts), *Non-preloaded structural bolting assemblies*

EN ISO 898-1, *Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread (ISO 898-1)*

EN ISO 898-2, *Mechanical properties of fasteners made of carbon steel and alloy steel - Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread (ISO 898-2)*

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

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

EN ISO 4042, *Fasteners - Electroplated coatings (ISO 4042)*

EN ISO 6789 (all parts), *Assembly tools for screws and nuts - Hand torque tools (ISO 6789)*

EN ISO 7089, *Plain washers - Normal series - Product grade A (ISO 7089)*

EN ISO 7090, *Plain washers, chamfered - Normal series - Product grade A (ISO 7090)*

EN ISO 7091, *Plain washers - Normal series - Product grade C (ISO 7091)*

EN ISO 7092, *Plain washers - Small series - Product grade A (ISO 7092)*

EN ISO 7093-1, *Plain washers - Large series - Part 1: Product grade A (ISO 7093-1)*

EN ISO 7094, *Plain washers - Extra large series - Product grade C (ISO 7094)*

EN ISO 10684, *Fasteners - Hot dip galvanized coatings (ISO 10684)*

EN ISO 21670, *Fasteners - Hexagon weld nuts with flange (ISO 21670)*

2.1.5 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*

2.1.6 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*

2.2 Preparation

EN ISO 286-2, *Geometrical product specifications (GPS) - ISO code system for tolerances on linear sizes - Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts (ISO 286-2)*

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

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

2.3 Welding

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

EN 1011-2, *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 ISO 3834 (all parts), *Quality requirements for fusion welding of metallic materials (ISO 3834)*

EN ISO 4063, *Welding and allied processes - Nomenclature of processes and reference numbers (ISO 4063)*

EN ISO 5817:2014, *Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality levels for imperfections (ISO 5817:2014)*

EN ISO 9606-1:2017, *Qualification testing of welders - Fusion welding - Part 1: Steels (ISO 9606-1:2017)*

EN ISO 9692-1, *Welding and allied processes - Types of 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)*

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

EN ISO 11970, *Specification and qualification of welding procedures for production welding of steel castings (ISO 11970)*

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

EN ISO 14554 (all parts), *Quality requirements for welding - Resistance welding of metallic materials (ISO 14554 series)*

EN ISO 14555, *Welding - Arc stud welding of metallic materials (ISO 14555)*

EN ISO 14731, *Welding coordination - Tasks and responsibilities (ISO 14731)*

EN ISO 14732, *Welding personnel - Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials (ISO 14732)*

EN ISO 15607, *Specification and qualification of welding procedures for metallic materials - General rules (ISO 15607)*

CEN ISO/TR 15608, *Welding — Guidelines for a metallic material grouping system*

EN ISO 15609 (all parts), *Specification and qualification of welding procedures for metallic materials - Welding procedure specification (ISO 15609)*

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

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

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

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

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)*

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)*

EN ISO 15614-12, *Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 12: Spot, seam and projection welding (ISO 15614-12)*

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

EN ISO 15620, *Welding - Friction welding of metallic materials (ISO 15620)*

EN ISO 17652-1, *Welding - Test for shop primers in relation to welding and allied processes - Part 1: General requirements (ISO 17652-1)*

EN ISO 17652-2, *Welding - Test for shop primers in relation to welding and allied processes - Part 2: Welding properties of shop primers (ISO 17652-2)*

EN ISO 17652-3, *Welding - Test for shop primers in relation to welding and allied processes - Part 3: Thermal cutting (ISO 17652-3)*

EN ISO 17652-4, *Welding - Test for shop primers in relation to welding and allied processes - Part 4: Emission of fumes and gases (ISO 17652-4)*

EN ISO 17660 (all parts), *Welding - Welding of reinforcing steel (ISO 17660 series)*

2.4 Testing

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

EN ISO 3452-1, *Non-destructive testing - Penetrant testing - Part 1: General principles (ISO 3452-1)*

EN ISO 6507 (all parts), *Metallic materials - Vickers hardness test - Part 1: Test method (ISO 6507 series)*

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

EN ISO 9712, *Non-destructive testing - Qualification and certification of NDT personnel (ISO 9712)*

EN ISO 17635, *Non-destructive testing of welds - General rules for metallic materials (ISO 17635)*

EN ISO 17636 (all parts), *Non-destructive testing of welds - Radiographic testing (ISO 17636 series)*

EN ISO 17637, *Non-destructive testing of welds - Visual testing of fusion-welded joints (ISO 17637)*

EN ISO 17638, *Non-destructive testing of welds - Magnetic particle testing (ISO 17638)*

EN ISO 17640, *Non-destructive testing of welds - Ultrasonic testing - Techniques, testing levels and assessment (ISO 17640)*

EN ISO 23279, *Non-destructive testing of welds - Ultrasonic testing - Characterization of indications in welds (ISO 23279)*

2.5 Erection

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

ISO 4463 (all parts), *Measurement methods for building - Setting-out and measurement*

2.6 Corrosion protection

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

EN ISO 2063 (all parts), *Thermal spraying - Metallic and other inorganic coatings - Zinc, aluminium and their alloys (ISO 2063 series)*

EN ISO 2808, *Paints and varnishes - Determination of film thickness (ISO 2808)*

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

EN ISO 8502 (all parts), *Preparation of steel substrates before application of paints and related products - Tests for the assessment of surface (ISO 8502)*

EN ISO 8503 (all parts), *Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates (ISO 8503)*

EN ISO 8504 (all parts), *Preparation of steel substrates before application of paints and related products - Surface preparation methods (ISO 8504)*

EN ISO 12670, *Thermal spraying - Components with thermally sprayed coatings - Technical supply conditions (ISO 12670)*

EN ISO 12679, *Thermal spraying - Recommendations for thermal spraying (ISO 12679)*

EN ISO 12944 (all parts), *Paints and varnishes - Corrosion protection of steel structures by protective paint systems (ISO 12944-1 series)*

EN ISO 14713-1:2017, *Zinc coatings - Guidelines and recommendations for the protection against corrosion of iron and steel in structures - Part 1: General principles of design and corrosion resistance (ISO 14713-1)*

EN ISO 14713-2, *Zinc coatings - Guidelines and recommendations for the protection against corrosion of iron and steel in structures - Part 2: Hot dip galvanizing (ISO 14713-2)*

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*

2.7 Miscellaneous

EN 1090-4, *Execution of steel structures and aluminium structures - Part 4: Technical requirements for cold-formed structural steel elements and cold-formed structures for roof, ceiling, floor and wall applications*

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*

EN 1993-1-9:2005, *Eurocode 3: Design of steel structures - Part 1-9: Fatigue*

EN 1993-2:2006, *Eurocode 3 - Design of steel structures - Part 2: Steel Bridges*

EN 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 (AQL) for lot-by-lot inspection*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
construction works
everything that is constructed or results from construction operations

Note 1 to entry: 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

3.5
structure
organized combination of connected parts designed to carry loads and provide adequate rigidity

[SOURCE: EN 1990:2002, 1.5.1.6]

3.6
manufacturing
activity required to produce and deliver a component

Note 1 to entry: 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
activity performed for the physical completion of the works

Note 1 to entry: i.e. manufacturing, erection 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 to entry: Execution specification includes requirements where this European Standard identifies items to be specified by provision of additional information or adoption of permitted options (see Annex A).

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
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

3.9
component
part of a steel structure, which may itself be an assembly of several smaller components

3.9.1
cold formed component
cold formed long products or profiled sheet having various cross section shapes, either open or with edges abutting, constant along their length, made from coated or uncoated hot or cold rolled flat products whose thicknesses are only slightly modified by the cold forming process (e.g. profiling, drawing, press forming, flanging, etc.)

[SOURCE: EN 10079:2007, 3.4.9]

3.10
preparation
activity performed on the constituent steel products to produce the parts ready for assembly and inclusion in components

Note 1 to entry: As relevant, this comprises e.g. identification, handling and storage, cutting, shaping and holing.

3.11
design basis method of erection
outline of a method of erection upon which the design of the structure is based

3.11.1
erection method statement
documentation describing the procedures to be used to erect a structure

3.12
inspection and test plan
ITP
plan that includes inspection and/or testing of documents and/or materials and/or workmanship

3.13
nonconformity
non-fulfilment of a requirement

[SOURCE: EN ISO 9000:2015, 3.6.9, modified]

3.14
supplementary NDT
supplementary non-destructive testing
NDT technique which is supplementary to visual examination (VT), e.g. magnetic particle (MT), penetrant (PT), eddy current (ET), ultrasonic (UT) or radiographic testing (RT)

3.15
tolerance
difference between the upper limit of size and the lower limit of size

Note 1 to entry: Tolerance is an absolute value without sign.

[SOURCE: ISO 1803:1997, 3.11, Notes 2 and 3 deleted]

3.15.1
essential tolerance
basic limit for a geometrical tolerance necessary to satisfy the design assumptions for structures in terms of mechanical resistance and stability

3.15.2
functional tolerance
geometrical tolerance, which might be required to meet a function other than mechanical resistance and stability, e.g. appearance or fit up

3.15.3
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

3.15.4
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.

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 EXC3 with EXC4 being based on EXC3 with further project specific requirements (e.g. see 7.6.1, 12.4.2.3 and 12.4.2.4).

The execution specification shall specify the relevant execution class or classes.

NOTE The requirements for the basis for the selection of execution classes are given in EN 1993-1-1:2005/A1:2014, Annex C.

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

4.1.3 Requirements for surface preparation for corrosion protection

With respect to the preparation of welds, edges and other areas with surface imperfections for the application of paint and related products, three preparation grades, denoted P1 to P3 according to EN ISO 8501-3, are given, for which requirement strictness increases from P1 to P3.

NOTE Preparation grades classify visible imperfections suitable for the application of paints and related products.

The execution specification shall specify the relevant preparation grades if appropriate.

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 and in Annex B:

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

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

c) an inspection and test plan specific to the works;

d) a procedure for handling changes and modifications;

e) a procedure for handling of nonconformities;

f) specified 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.

A quality plan shall include:

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

   1) review of specification requirements against process capabilities;

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

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

b) quality documentation prior to execution. 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 which demonstrate qualification or certification of implemented resources.

Annex C gives a checklist for the content of a quality plan recommended for the execution of structural steelwork.

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. The relevant properties to be specified shall be as follows:

a) strength (yield and tensile);

b) elongation;

c) stress reduction of area requirements (STRA), if required;

d) tolerances on dimensions and shape;

e) impact strength or toughness, if required;

f) heat treatment delivery condition;

g) through thickness requirements (Z-quality), if required;

h) limits on internal discontinuities or cracks in zones to be welded, if required.

In addition, if the steel is to be welded, its weldability shall be declared as follows:

i) classification in accordance with the materials grouping system defined in CEN ISO/TR 15608 or;

j) a maximum limit for the carbon equivalent of the steel, or;

k) a declaration of its chemical composition in sufficient detail for its carbon equivalent to be calculated.

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. Type 3.2 inspection documents are also suitable if Type 3.1 documents are listed in Table 1.

For structural bolting assemblies and other fasteners, inspection documents according to the EN ISO 16228 series may be used instead of documents according to EN 10204.

Table 1 — Inspection documents for metallic products

Constituent product	Inspection documents
Structural steels (Tables 2 and 3)	
Structural steel grade ≤ S275	2.2 a, b
Structural steel grade > S275	3.1 b
Stainless steels (Table 4)	
Minimum 0,2 % tensile yield strength ≤ 240 MPa	2.2
Minimum 0,2 % tensile yield strength > 240 MPa	3.1
Steel castings	3.1 c
Welding consumables (Table 5)	2.2
Structural bolting assemblies to the EN 14399 series	3.1 d, e
Structural bolting assemblies to the EN 15048 series	2.1
Bolts f, nuts f, or washers f	2.1
Solid rivets for hot riveting	2.1
Self-tapping and self-drilling screws and blind rivets	2.1
Studs for arc stud welding	3.1
Expansion joints for bridges	3.1
High strength cables	3.1
Structural bearings	3.1

a Inspection document 3.1 if specified minimum yield strength 275 MPa and specified impact energy tested at a temperature less than 0 °C.

b EN 10025–1:2004 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 shall include Al, Nb, and Ti.

c Inspection document 2.2 if specified minimum yield strength ≤ 355 MPa and specified impact energy tested at a temperature of 20 °C.

d If assemblies are marked with a manufacturing lot number and the manufacturer can trace the measured characteristic values from the internal (factory) production control records on the basis of this number, the 3.1 inspection certificate as in EN 10204 may be omitted.

e The inspection documents shall include the results of the suitability tests.

f Applicable if bolts, nuts or washers are supplied for use in non-preloaded applications and not as a component of a fastener assembly to the EN 14399 series or the EN 15048 series.

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 individual constituent product is specified.

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

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 nonconforming 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	EN 10365	EN 10034
Hot-rolled taper flange I sections		EN 10365	EN 10024
Channels		EN 10365	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 EN 10027–2 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 series, EN 10268	EN 10029, EN 10048, EN 10051, EN 10131, EN 10140
Cold reduced steels	ISO 4997	EN 10131
Continuously coated hot dip coated steels	EN 10346	EN 10143
Continuously organic coated steel flat products	EN 10169	EN 10169
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 10088–4	EN ISO 9444-2, EN ISO 9445 (all parts), EN ISO 18286
Tubes (welded)	EN 10296–2	EN ISO 1127
Tubes (seamless)	EN 10297–2	
Bars, rods and sections	EN 10088–5	EN 10017, EN 10058, EN 10059, EN 10060, EN 10061
Steel designations by name and number are given in EN 10088-1.		

For structural steel products other than those conforming to the requirements of the relevant European product standards as listed in Tables 2, 3 and 4, a declaration of the characteristics of the steel products shall be compared with the required properties given in the execution specification (see 5.1).

With respect to the properties that are declared, the basis for the declarations shall be provided.

NOTE For instance, reference standards for test methods used to establish values for declared properties, whether properties are specific to an identified lot, cast or heat; and whether chemical properties are based on ladle or product analysis.

5.3.2 Thickness tolerances

Unless otherwise specified, the thickness tolerances for structural steel plates shall be class A in accordance with EN 10029 for hot rolled steel plates and EN ISO 18286 for hot-rolled stainless steel plates.

5.3.3 Surface conditions

For carbon steels, surface condition requirements are as follows:

a) class A1 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.

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

a) sheet, plate and strip: in accordance with the requirements of EN 10088-4;

b) bars, rods and sections: in accordance with the requirements of EN 10088-5.

The execution specification shall specify additional requirements related to the following items: special restrictions on either surface imperfections or repair of surface defects by grinding in accordance with the EN 10163 series, or with the EN 10088-4 and EN 10088-5 for stainless steel, if required.

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

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 Additional properties

Unless otherwise specified, internal discontinuity quality class S1 of EN 10160 shall be used 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 Number (PREN) or accelerated corrosion testing. The PREN shall be given by $(1 \times \%Cr + 3{,}3 \times \%Mo + 16 \times \%N)$, in which the elements are in mass fraction percent, 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. The technical delivery conditions (grades, qualities and, if appropriate, surface conditions) shall be specified together with any required options permitted by the product standard including necessary information and options as required in EN 1559-1 and EN 1559-2. Unless otherwise specified the properties of delivered castings shall be evaluated by testing.

Unless otherwise specified, the testing shall include:

a) 100 % visual inspection;

b) the following destructive tests on items taken at random during production. The execution specification shall specify whether the items shall be destructive product samples, extension pieces or separate items cast simultaneously:

   1) tensile and elongation tests (one unit per melt);

   2) impact tests (three units per melt);

   3) reduction of area test (one unit per melt if relevant);

   4) chemical analysis (one unit per melt);

   5) microscopic examination of cross-sections (one unit per melt).

c) the following non-destructive tests on items taken at random from each manufacturing lot:

   6) MT or PT of surface-breaking discontinuities on 10 % of each manufacturing lot, and;

   7) UT or RT to detect sub-surface discontinuities on 10 % of each manufacturing lot.

Unless otherwise specified, the acceptance criteria for cast steel components are:

— SM2 and LM3/AM3 to EN 1369 for MT;

— Severity level 2 to EN 12680-1 for UT;

— Severity level 3 for RT.

5.5 Welding consumables

All welding consumables shall conform to the requirements of 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 ISO 14171
Covered electrodes for manual arc welding of high strength steels	EN ISO 18275
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 ISO 14174
Covered electrodes for manual arc welding of stainless and heat resisting steels	EN ISO 3581
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 ISO 26304
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.

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 % Ni 0,5 % Mo
135	Matching	2,5 % Ni	1 % Ni 0,5 % Mo
121,122	Matching	2 % Ni	1 % Ni 0,5 % Mo
Matching: ≥ 0,4 % 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, unless otherwise specified.

5.6 Mechanical fasteners

5.6.1 General

The corrosion resistance of the bolting assemblies, other 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.

Electroplated coatings of fasteners shall conform to EN ISO 4042.

Non-electrolytically applied zinc flake coatings of fasteners shall conform to EN ISO 10683.

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.

NOTE Attention is drawn to the risk of hydrogen embrittlement during electroplating or hot dip galvanizing of bolting assemblies with property class 10.9.

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 steel, alloy steel and stainless steel structural bolting assemblies for non-preloaded applications shall conform to the requirements of the EN 15048 series.

Assemblies according to EN 14399 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 technical delivery conditions shall be specified for:

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

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

c) weather resistant assemblies (see 5.6.6).

Fasteners according to EN ISO 898-1 and EN ISO 898-2 shall not be used to join stainless steels according to the EN 10088-4 and EN 10088-5 unless otherwise specified. If insulation kits are to be used full details of their use shall be specified.

The shanks of pins shall be to tolerance class h13 to EN ISO 286-2 (b11 if coated).

NOTE These values are the same as those for fit bolts to EN 14399–8.

5.6.4 Structural bolting assemblies for preloading

High strength structural bolting assemblies for preloading include system HR, system HV and HRC bolting assemblies. They shall conform to the testing requirements in EN 14399-2 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 EN 14399–10	EN 14399–5 EN 14399–6

Stainless steel bolting assemblies shall not be used in preloaded applications unless otherwise specified. If used they shall be considered as special fasteners (see 5.6.11).

5.6.5 Direct tension indicators

Direct tension indicators and associated HN/HB nut face and bolt face washers shall be in accordance with EN 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.

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.

Unless otherwise specified, reinforcing steels shall not be used. If their use is specified, the steel shall conform to EN 10080 and the grade shall be specified.

NOTE EN 13670 specifies requirements for reinforcing steel bars used as foundation bolts or anchors.

5.6.8 Locking devices

If required, devices which effectively prevent loosening or loss of preload of the assembly if subjected to impact, significant vibration or cyclic loading, shall be specified.

For the prevention of loosening, prevailing torque nuts from EN ISO 7040, EN ISO 7042, EN ISO 7719 and EN ISO 10511 and the performance requirements given in EN ISO 2320 may be used unless otherwise specified.

5.6.9 Washers

5.6.9.1 Plain washers

Washers supplied as part of a fastener assembly shall comply with the relevant product standard for that assembly.

Washers supplied separately may be used in non-preloaded applications and shall be in accordance with EN ISO 7089, EN ISO 7090, EN ISO 7091, EN ISO 7092, EN ISO 7093-1 or EN ISO 7094 for carbon steel, EN ISO 7089, EN ISO 7090, EN ISO 7092 or EN ISO 7093-1 for stainless steels.

5.6.9.2 Taper washers

Taper washers shall meet the hardness and other requirements specified for plain washers as specified in 5.6.9.1 with the exception of dimensions applicable to shape, which shall be specified.

5.6.9.3 Plate washers

Plate washers shall be dimensioned with nominal clearances according to Table 11 and with dimensions that ensure that the washer overlaps the connected component by at least as much as a standard plain washer would when used with normal round holes.

5.6.10 Solid rivets for hot riveting

Solid rivets for hot riveting shall comply with the relevant product standard, which shall be specified.

5.6.11 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 For the use of special fasteners, see 8.8.

Resin injection bolts shall be classified as special fasteners.

5.6.12 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 5.6.6 to 5.6.11 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 shall be in accordance with the requirements of the product standard and should contain the following information in a legible and durable form:

   1) manufacturer’s identification and, if relevant, lot numbers;

   2) type of fastener and material and, if appropriate, its assembly;

3) protective coating.

c) marking of fasteners shall be in accordance with the requirements of the product standard.

5.7 Studs and shear connectors

Studs for arc stud welding shall comply with the requirements of EN ISO 13918.

Studs or shear connectors other than the stud types in EN ISO 13918 shall be classified as special fasteners and comply with 5.6.11.

5.8 Reinforcing steel welded to structural steel

Reinforcing steels to be welded to structural steel shall be suitable for welding according to EN 10080.

5.9 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.

5.10 Expansion joints for bridges

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

5.11 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.

5.12 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 products for inclusion into components, and for assembly of 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.

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 S500;

b) they are not permitted for stainless steels;

c) 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 minimized. 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'.
Stainless steels	
9	Handling and storage of stainless steel to prevent contamination by fixtures or manipulators etc. Careful storage of stainless steel, so that the surfaces are protected from damage or contamination
10	If appropriate, use of protective film or other coating, to be left on as long as practicable
11	Avoidance of storage in salt-laden humid atmospheres
12	Protection of storage racks by suitable wooden, rubber or plastic battens or sheaths to avoid carbon steel, copper-containing, lead etc. rubbing surfaces
13	Use of markers containing chloride or sulphide prohibited NOTE An alternative is to use protective film and apply all marks only into this film.
14	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
15	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.
16	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	
17	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.

Known and recognized 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. For some cutting methods, precautions should be taken if the cut edges are to be free edges (i.e. not to be subsequently welded) for components subject to fatigue (see 6.4.4).

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 any damage to 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 automated thermal cutting processes shall be checked annually as set out below.

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

a) a straight cut from the thickest constituent product;

b) a straight cut from the thinnest constituent product;

c) a sharp corner from a representative thickness;

d) 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 of the cut surface. The sharp corner and curved samples shall be visually inspected to establish that they produce edges of equivalent standard to the straight cuts.

Alternatively, the guidance given in Annex D may be used to check the capability of automated thermal cutting processes.

The quality requirements for cut surfaces to be left as free edges (i.e. not to be subsequently incorporated into a weld) shall be according to Table 9 when assessed in accordance with EN ISO 9013, unless otherwise specified.

Table 9 — Quality of the cut surfaces

Execution classes	Perpendicularity or angularity tolerance, u	Mean height of the profile, Rz5
EXC1	Cut edges to be free from significant irregularities and dross shall be removed	
EXC2	Range 5	Range 4
EXC3 and EXC4	Range 4	Range 4

6.4.4 Hardness of free edge surfaces

Processes that are likely to produce local hardness shall have their capability checked.

For carbon steels ≥ S460 the hardness of free edge surfaces shall be no more than 450 (HV10).

The execution specification may specify other requirements for the hardness of free edge surfaces.

NOTE 1 These specified requirements can be necessary if the free edge is subject to fatigue or impact forces or susceptible to hydrogen embrittlement or to ensure that the free edge is suitable for preparation according to 10.2 prior to application of paints and related products. For free edges to be hot dip galvanized, see EN ISO 14713-2.

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 the EN ISO 6507 series.

NOTE 2 The requirements for checking of hardness after welding are included in procedure testing (see 7.4.1).

For thermal cutting, guidance is given in Annex D.

In order to limit the hardness of free edge surfaces, preheating of material shall be applied as necessary.

6.5 Shaping

6.5.1 General

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

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 in the relevant product standard and to the recommendations of the steel manufacturer. Unless otherwise specified, hot forming of stainless steels is not permitted.

For steels according to EN 10025-4 and in the delivery condition +M according to EN 10025-2 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 components 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 (600 °C to 650 °C) 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 normalizing 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

6.5.3.1 General

If distortion is to be corrected by flame straightening, this shall be undertaken by local application of heat.

For steel grades greater than S355, and if specified for other grades, a documented 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) identification of workers entitled to apply the process.

The procedure shall be qualified based on the results of tensile, impact and hardness tests. With respect to the thermally heated zone, the location used for temperature measurement and the locations and orientation for the test samples to be used shall be specified.

6.5.3.2 Additional requirements for stainless steels

Flame straightening of stainless steels should be avoided especially for duplex, low nickel austenitic and martensitic grades. If it is inevitable, the maximum temperatures shall be kept as low as possible, and the period of exposure to heat shall be kept as short as possible. In addition, the following conditions shall be considered:

a) the surface shall be free from sulfurous agents and other impurities such as labelling, iron dust and grease;

b) the acetylene oxygen flame shall be adjusted neutrally or slightly oxygen-excessive;

c) the thermal exposure time (preheating + time at temperature + cooling off time) should be as short as possible. Cooling off shall be done by using water or compressed air;

d) the conditions in Table 10 shall be observed;

e) arresters or striking tools as well as other tools should consist of CrNi-steel or should be chromeplated.

After straightening, annealing colours and oxide scales shall be completely removed using suitable measures.

Flame straightening shall only be performed by competent staff under supervision of the welding coordinator.

It should be noted that for cold-worked stainless steels, softening due to flame straightening may affect the mechanical properties.

Table 10 — Flame straightening conditions for stainless steels

Steel grade	Temperature of flame straightening (°C)	Radiant heat colour	Maximum exposure time (minutes)
Ferritic steels	500 - 600	Blue-grey until commencement of dark red	4
Austenitic steels	650 - 750	Brown-red to dark red	12
Austenitic-ferritic steels	500 - 600	Blue-grey until commencement of dark red	8

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 carbon or alloy 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.

b) For carbon or alloy steels, 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;

c) For annealed stainless steels up to a thickness of 3 mm, unless otherwise specified, the minimum inside bend radii r to be formed shall be:

   1) $r = 0$ for austenitic grades;

   2) $r = t$ for austenitic-ferritic and ferritic grades;

   where t is the thickness of the material or the diameter of rods.

d) For other stainless steels and thicknesses, unless otherwise specified, the minimum inside bend radii r to be formed shall be:

$r = (4{,}2 - A_5/10)\ t$ for values of A_5 limited to 42 and where t is the plate thickness or diameter of rods.

e) A_5 is the minimum elongation at fracture in percent according to the reference standard relevant to the annealed or cold-worked condition of the material as appropriate;

f) If the values for elongation at fracture A_5 are lower in transverse direction, this shall be taken into account when bending in transverse direction by using these values in the formula above;

NOTE 1 The EN 10088 series provides values for elongation at fracture A_5. 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 2 The power requirements 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 austenitic-ferritic steels).

Unless otherwise specified in prEN 1090-4 for cold formed components and sheeting:

g) Cold formed sections may be shaped by cranking, smooth curving or crimping as appropriate to the materials to be used;

h) 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 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.

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

j) 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) the longitudinal seam weld 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 bolting assemblies. These terms may be used also to designate clearances for non-preloaded bolting assemblies.

The execution specification shall specify special dimensions 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:

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

b) 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** [a]	**14**	**16**	**18**	**20**	**22**	**24**	**27 to 36** [b]
Normal round holes [c]	1 [d e]		2					3
Oversize round holes	3		4				6	8
Short slotted holes (on the overall length) [f]	4		6				8	10
Long slotted holes (on the overall length) [f]	1,5 d							

[a] Also applicable to diameters less than 12 mm, unless otherwise specified.

[b] Also applicable to diameters more than 36 mm, unless otherwise specified.

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

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

[e] Bolts with nominal diameter 12 mm and 14 mm, or countersunk bolts may also be used in 2 mm clearance holes if specified.

[f] 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 solid rivets for hot riveting, the nominal hole diameter shall be specified.

For countersunk bolts or solid rivets for hot riveting, 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.

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 EN ISO 286-2;

b) thermally cut and other holes: –0,5/+0,5 mm.

the hole diameter being taken as the average of the maximum and minimum diameters (see Figure 1).

6.6.3 Execution of holing

Holes for fasteners or pins may be formed by any process (e.g. 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 1,4 times the nominal diameter of the hole, or for a non-circular hole, its minimum dimension. Outside of these dimensional limitations, holes may be formed by punching unless otherwise specified.

Where untreated punched holes are not permitted, holes may be punched at least 2mm less than full size and then reamed or drilled until all trace of the original punched surface has been removed.

NOTE Generally, punching without subsequent reaming or drilling would not be suitable in bolted joints where any of the following conditions applies:

— the joint is subject to cyclic or seismic loading, or;

— it is a lap joint where the fasteners are above Grade 8.8, or;

— the joint is designed to be slip resistant.

The process capability of punching used for holing shall be checked annually as follows:

a) a representative number of samples shall be produced from procedure tests on constituent product encompassing the range of hole diameters, constituent product thickness and grades processed;

b) hole sizes shall be checked at both ends of each hole using go/no go gauges or other appropriate methods. Holes shall comply with the appropriate tolerances specified in 6.6.2.

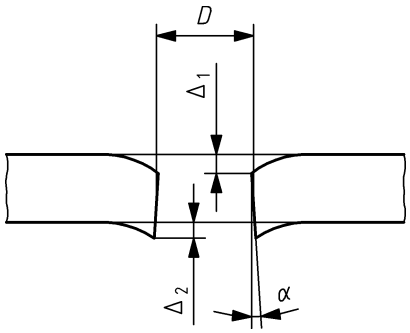
If the process does not conform, it shall not be used until corrected. It may be used on a restricted range of constituent products and hole sizes that do produce conforming results.

Holes formed by punching or thermal cutting shall also conform to the following:

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

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

e) 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 ; 2 mm)

$\alpha \leq 4°$ (i.e. 7 %)

Figure 1 — Permitted distortions of punched or thermally cut holes

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 thermal cutting, unless otherwise specified.

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 of the outer plies.

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°.

Unless otherwise specified, re-entrant corners and notches shall be rounded off with a minimum radius of 5mm.

Unless otherwise specified, punched cut outs are permitted. At punched cut outs in plates over 16 mm in thickness, the deformed materials shall be removed by grinding.

6.8 Full contact bearing surfaces

If full contact bearing surfaces are specified, the cutting length, squareness of ends and flatness of bearing surfaces 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 shall be avoided.

Drifting to align holes, other than those for fitted bolts or fitted pins, shall be carried out in such a way that the elongation does not exceed the values given for class 1 in Table B.8.

If the elongation exceeds this value, 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 can 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 if appropriate.

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 the EN ISO 3834 series or the EN ISO 14554 series as applicable.

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

The welding of reinforcing steel to structural steel shall be performed in accordance with the recommendations given in the EN ISO 17660 series.

Arc welding of ferritic steels and stainless steels shall be in accordance with the requirements and recommendations of EN 1011-1, EN 1011-2 and EN 1011-3 as relevant.

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

— EXC1: EN ISO 3834-4 “Elementary quality requirements”;

— EXC2: EN ISO 3834-3 “Standard quality requirements”;

— EXC3 and EXC4: EN ISO 3834-2 “Comprehensive quality requirements”.

The scope of application of EXC1 may be restricted in accordance with national provisions arising from EN 1993-1-1:2005/A1:2014, Annex C (see 4.1.2).

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 the EN ISO 3834 series.

7.2.2 Content of a welding plan

The welding plan shall include, as relevant:

a) the welding procedure specifications identified to the relevant welding procedure qualification, including welding consumables, 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) measures to control the heat input to avoid local hardness in small weld runs;

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

j) weld profile and finish for stainless steels;

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

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

m) requirements for weld identification;

n) 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.

Unless otherwise specified, the conditions for welding cold formed zones should be according to EN 1993-1-8:2005, 4.14.

7.3 Welding processes

Welding processes that may be used, and their associated reference numbers, are defined in EN ISO 4063.

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 the EN ISO 15609 series, EN ISO 14555, EN ISO 15620 or the EN ISO 17660 series, as relevant.

If specified, special deposition conditions for tack welds shall be included in the WPS. For joints in hollow section lattice structures, 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 shall be defined (see Annex E).

The specification and qualification of welding procedures shall be in accordance with EN ISO 15607.

Although there are no specific requirements for welding procedure specifications to EN ISO 15607 in EN ISO 3834-4, the execution specification may specify that, for EXC1, appropriate work instructions that specify the welding process, consumables and welding parameters to be used shall be provided.

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

The qualification of the welding procedure for processes 111, 114, 12, 13 and 14 depends on the execution class, the parent metal and the degree of mechanization in accordance with Table 12.

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

Method of qualification		EXC2	EXC3 EXC4
Welding procedure test	EN ISO 15614-1 [a] EN ISO 17660-1 / EN ISO 17660-2 [b]	**X**	**X**
Pre-production welding test	EN ISO 15613 EN ISO 17660-1 / EN ISO 17660-2 [b]	**X**	**X**
Standard welding procedure	EN ISO 15612	**X**	**X** [c]
Previous welding experience	EN ISO 15611	**X**	—
Tested welding consumables	EN ISO 15610		
X Permitted — Not permitted			
[a] Qualification of welding procedures to EN ISO 15614-1:2017 shall be to Level 2. [b] Shall be used only for joints between reinforcing steels and other steel components. [c] If permitted by the execution specification.			

If a qualification procedure is required for fillets welds on steel grades ≥ S460, a cruciform tensile test shall be performed in accordance with EN ISO 9018. Alternatively and if permitted by the execution specification, for fillets welds on steel grades ≥ S460 instead of a test in accordance with EN ISO 9018, if the fillet weld throat for an undermatched consumable is increased to compensate then an all weld metal tensile test shall be performed and compared with the actual tensile strength declared for the consumable.

With respect to cruciform tensile testing, three cross-tensile specimens 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 ≥ 0,8 R_m (with R_m = nominal tensile strength of the used parent metal).

For the first pass of a single or multi pass deep penetration fillet welding using a fully mechanized process, a welding procedure test according to EN ISO 15614-1 shall be performed and examined for the range of nominal throat thickness which occurs during production. The examination shall include three macro-sections, one from the beginning, one from the middle and one from the end of one test piece. The minimum value of deep penetration shall be determined by measuring the actual values in the macro sections.

If welding on shop primers, welding procedure tests shall be carried out on the maximum permitted primer thickness (nominal + tolerance). Shop primers shall demonstrate their weldability according to EN ISO 17652-1 to EN ISO 17652-4. The welding procedure is qualified if the imperfections in the test piece are within the specified limits of quality level B according to EN ISO 5817 except for porosity which shall be as follows:

a) no linear porosity (cluster of porosity with distance between pores ≤ diameter of pores);

b) 8 % maximum according to EN ISO 5817:2014, Annex A for components generally or 4 % maximum for components specified as being subject to fatigue.

For stainless steels, welding procedure tests according to EN ISO 15614-1 shall be performed with the exception of the steel grades with the material numbers 1.4301, 1.4307, 1.4541, 1.4401, 1.4404, 1.4571 in the non-work-hardened condition as well as joints between these materials and with structural carbon steels.

Unless otherwise specified, if EN ISO 15613 or EN ISO 15614-1 qualification procedures are used, the following conditions apply:

a) If impact tests are a requirement of EN ISO 15614-1 then for EN ISO 15613 as well, they shall be carried out at the lowest temperature required for impact testing of the material qualities being joined, including the lowest temperature testing option where such options exist for a particular Charpy quality.

b) 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.

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, 784 and 786

Welding processes (according to EN ISO 4063**)**		**Welding procedure specification (WPS)**	**Qualification of the welding procedure**
Reference number	**Nomenclature**		
21 22 23	Spot welding Seam welding Projection welding	EN ISO 15609-5	EN ISO 15614-12
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
784	Short-cycle drawn arc stud welding		
786	Capacitor discharge stud welding with tip ignition		

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 shall be carried out in accordance with the relevant standard of qualification, e.g. EN ISO 14555, EN ISO 11970, EN ISO 17660-1, EN ISO 17660-2, EN ISO 17652-2.

7.4.2 Welders and welding operators

7.4.2.1 General

Welders shall be qualified in accordance with EN ISO 9606-1 and welding operators in accordance with EN ISO 14732.

For the welding of components to EXC1 in facilities working in accordance with EN ISO 3834-4, welder qualifications shall be revalidated according to EN ISO 9606-1:2017, 9.3.a) or 9.3.b) and welding operators shall be revalidated according to EN ISO 14732:2013, 5.3.a) or 5.3.b).

Welders of reinforcing steel shall be qualified in accordance with EN ISO 17660-1 or EN ISO 17660-2.

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

7.4.2.2 Branch connections

Welders of a hollow section branch connection with angles less than 60° as defined in EN 1993-1-8 shall be qualified as follows, unless otherwise specified:

a) test piece dimensions, weld details and welding positions shall be typical of those used in production;

b) for qualifying welding of circular onto circular hollow sections, test pieces for examination shall be taken from each of the four positions A, B, C and D shown in Figures E.2 and E.3 in Annex E;

c) for qualifying welding of circular onto square or rectangular hollow sections, test pieces for examination shall be taken from each of the two positions C and D shown in Figures E.4 and E.5 in Annex E;

d) test pieces shall be examined by VT and macroscopic examination to EN ISO 17639;

e) qualification shall be in accordance with the requirements of EN ISO 9606-1.

7.4.3 Welding coordination

For EXC1, a sufficient supervision during the execution of welding works shall be provided as specified in EN ISO 3834-4.

For EXC2, EXC3 and EXC4, welding coordination shall be maintained during the execution of welding processes 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 in which B, S and C are respectively basic, specific and comprehensive knowledge as specified in EN ISO 14731.

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

The technical knowledge of welding coordination personnel for welding reinforcement steel shall be in accordance with EN ISO 17660-1.

The welding coordinator is responsible for the process of qualification of the welders/operators. Welding coordinators may act as examiners. If qualification is undertaken by external examiners/examination bodies, this should be done in accordance with the procedures of EN ISO/IEC 17024 or EN ISO/IEC 17020.

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

EXC	Steels (steel group)	Reference standards	Thickness (mm)		
			t ≤ 25 [a]	**25 < *t* ≤ 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 ≤ 25	25 ≤ t ≤ 50	*t* > 50
EXC2	Austenitic (8) Ferritic (7.1)	EN 10088–4:2009, Table 3 EN 10088–5:2009, Table 4 EN 10296–2:2005, Table 1 EN 10297–2:2005, Table 2	B	S	C
	Austenitic-ferritic (10)	EN 10088–4:2009, Table 4 EN 10088–5:2009, Table 5 EN 10296–2:2005, Table 1 EN 10297–2:2005, Table 3	S	C	C
EXC3	Austenitic (8) Ferritic (7.1)	EN 10088–4:2009, Table 3 EN 10088–5:2009, Table 4 EN 10296–2:2005, Table 1 EN 10297–2:2005, Table 2	S	C	C
	Austenitic-ferritic (10)	EN 10088–4:2009, Table 4 EN 10088–5:2009, 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 preparations shall be suitable for welding process.

Tolerances for joints preparations and fit-up shall be given in the WPSs.

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.

If cope holes are provided to ensure accessibility, they shall have a minimum radius of 40 mm unless otherwise specified.

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 unacceptable notches or other imperfections in joint geometry are corrected by welding a qualified procedure shall be used, and the area shall be subsequently ground smooth.

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 zinc).

For EXC1 prefabrication primers (shop primers) may be left on the fusion faces only if they do not adversely affect the welding process. For EXC2, EXC3 and EXC4, prefabrication primers shall not be left on the fusion faces or heat affected zone, unless welding procedure tests in accordance with EN ISO 15614-1 or EN ISO 15613 have been completed using such prefabrication primers.

NOTE 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.

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.

Welding consumables showing signs of damage 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 (see EN 1011-1).

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, when required, shall be carried out in accordance with EN ISO 13916, EN 1011-2 and/or EN 1011-3.

If required, preheat shall be undertaken according to the applicable WPS and be 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.

Possible restrictions on the use of temporary attachments for EXC3 and EXC4 shall be specified in the execution specification.

The removal of temporary welded attachments by cutting, gouging or chipping shall be carried out in such a way that the parent metal is not damaged and shall subsequently be carefully ground smooth. The removal locations shall be visually inspected and for steel grades ≥ S355 shall be subjected to NDT. Chipping and gouging are not permitted on steel grades ≥ S460 or on components subject to fatigue, unless otherwise specified.

After removal, 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, EXC3 and EXC4, tack welds shall be made using a welding procedure specification based on a suitable 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. Tack welds with impermissible defects, such as cracks, 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 to EN ISO 5817:2014) quality levels apply provided that the throat thickness is maintained in accordance with (5213 to EN ISO 5817:2014);

c) that for bridge decks particular manufacturing requirements apply, e.g. for the throat thickness of fillet welds, see 7.5.17 and Table B.21.

7.5.8.2 Fillet welds on member connections

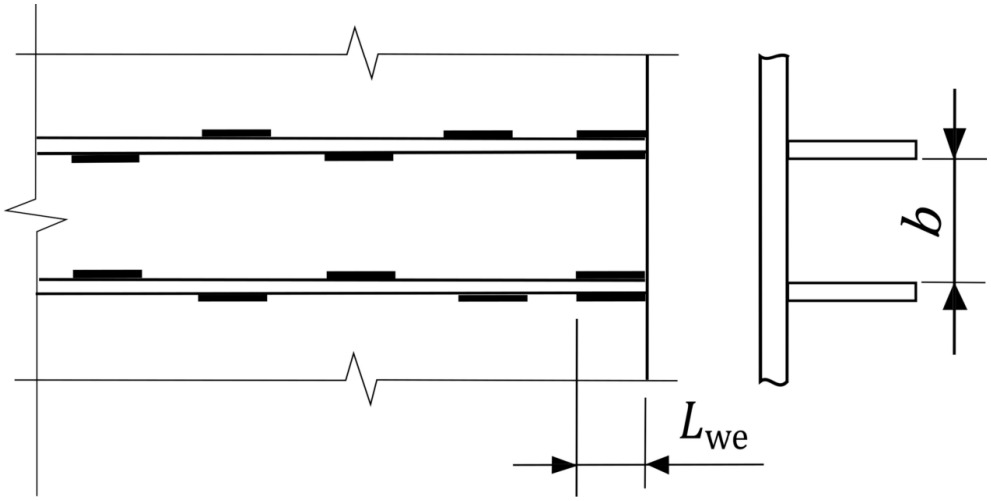
Fillet welds terminating at the ends or sides of components shall be returned continuously around the corners for a distance of not less than twice the leg length of the weld unless access or configuration renders this impracticable or unless otherwise specified.

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 welds 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 (L_{we}) shall not be less than 75 % of the transverse spacing between them (b) (see Figure 2).



$L_{we} \geq 0{,}75\ b$

Figure 2 — Intermittent fillet welds

7.5.9 Butt welds

7.5.9.1 General

The execution specification shall specify the location of butt welds used as splices to accommodate available lengths of constituent products.

NOTE This allows verification of consistency with the 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 for full penetration transverse butt welds. If specified for EXC2, EXC3 and EXC4 run-on/run-off pieces shall be used for full penetration longitudinal butt welds or partial penetration butt welds (transverse or longitudinal). 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.

The execution specification shall specify if excess weld metal shall be removed to a flush surface.

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 preferably 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 eliminate unacceptable imperfections in the 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 and/or surface layer 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.

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.

Procedure testing undertaken in accordance with EN ISO 14555 shall be consistent with the application.

NOTE For example, the procedure test may require stud welding through galvanized decking sheets.

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:

1) width: at least 8 mm more than the thickness of the part containing it;
2) 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 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.

7.5.15 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 EN ISO 17663.

7.5.16 Execution of welding

Precautions shall be taken to avoid stray arcing, and if stray arcs do occur outside the weld fusion face, the surface of the steel shall be lightly ground and checked. Visual checking for steel grades ≥ S460 and other grades if specified, should be supplemented by penetrant or magnetic particle testing.

Precautions shall be taken to minimize weld spatter. Unless otherwise specified, for steel grades ≥ S460 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.

7.5.17 Welding of orthotropic 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

7.6.1 Routine requirements

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

Unless otherwise specified, for EXC1, EXC2 and EXC3 the acceptance criteria for weld imperfections shall be as follows, with reference to EN ISO 5817:2014, 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:

a) EXC1 quality level D except quality level C for “Insufficient throat” (5213);

b) EXC2 quality level C except quality level D for “Overlap” (506), “Stray arc” (601) and “End crater pipe” (2025) and quality level B for “Insufficient throat” (5213);

c) EXC3 quality level B.

NOTE Welds in connections designed according to EN 1993–1–8 generally require quality level defined for EXC2.

For EXC4 the weld shall meet the requirements of EXC3 as a minimum. Additional requirements with respect to identified welds shall be specified.

7.6.2 Fatigue requirements

Unless otherwise specified, for welds subject to fatigue designed according to EN 1993-1-9, the execution specification shall specify the relevant acceptance criteria in terms of the detail category (DC) for the welded joint location.

For EXC2, EXC3 and EXC4, in addition to the criteria specified in 7.6.1, the acceptance criteria for welds may be specified in accordance with EN ISO 5817:2014, Annex C as follows:

a) DC not exceeding 63: Quality level C 63;

b) DC above 63 and not exceeding 90: Quality level B 90;

c) DC above 90 and not exceeding 125: Quality level B 125.

The execution specification shall specify execution requirements that are necessary to comply with the execution requirements given in of EN 1993-1-9:2005, Tables 8.1 to 8.8 and/or of EN 1993-2:2006, Annex C.

7.6.3 Orthotropic bridge decks

If specified in the execution specification, welds in orthotropic bridge decks, as shown in EN 1993-1-9:2005, Table 8.8, shall meet the requirements of 7.6.1 together with the requirements of EN 1993-2:2006.

7.7 Welding of stainless 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.

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 1 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.

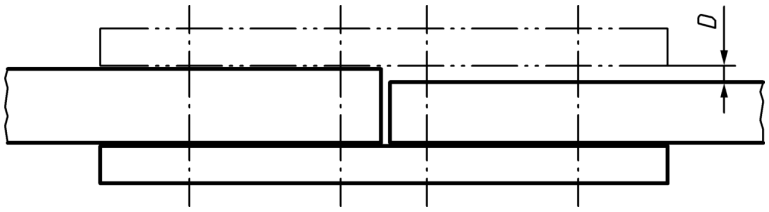


Figure 3 — Difference of thickness between components of a common ply

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 devices are to be used to secure the bolted assembly.

Bolted connections with small ratio of clamp lengths relative to bolt diameter subject to significant vibrations, such as storage racks, shall use a locking method.

Unless otherwise specified, preloaded assemblies do not require additional locking devices.

Bolts and nuts shall not be welded, unless otherwise specified. This restriction does not apply to special weld nuts according to e.g. EN ISO 21670 or weldable studs.

8.2.2 Bolts

The nominal fastener diameter used for structural bolting shall be at least M12, unless otherwise specified together with the associated requirements.

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 or additional locking devices to the end of the bolt for preloaded and non-preloaded assemblies.

If it is intended that a connection utilizes 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.

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 bolting assemblies in accordance with the EN 14399 series clamp lengths and grip lengths shall be chosen in accordance with the relevant product standards.

The tabulated nominal clamp lengths and grip lengths in the EN 14399 series take into account that between the bearing surface of the nut and the unthreaded part of the shank in assemblies according to EN 14399–4 and EN 14399–8 nominally at least two full threads and in assemblies according to EN 14399–3, EN 14399–7 and EN 14399–10 nominally at least four full threads shall remain clear.

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 assembly lot of bolting assemblies their compatibility may be checked by hand assembly before installation;

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

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

8.2.4 Washers

Washers are not required for use with non-preloaded bolting assemblies in normal round holes, unless otherwise specified. 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 necessary under both bolt head and the nut, unless otherwise specified.

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 used with steel grade S235 washers shall be used under both the bolt head and the nut;

c) unless the use of washers under both the bolt head and the nut is specified, for 10.9 bolts used with steel grades above S235 washers shall be used under the bolt head or the nut, whichever is to be rotated.

The allowable adjustment of grip length for preloaded and non-preloaded bolting assemblies is given in Table 16.

Plate washers according to 5.6.9.3 shall be used for connections with slotted and oversized holes unless otherwise specified.

Table 16 — Allowable adjustment of grip length for preloaded and non-preloaded bolting assemblies

Preloaded bolting assemblies[a]	Non-preloaded bolting assemblies
In addition to the minimum specified washer/s up to two additional washers[b] or one plate washer or one washer[b] and one plate washer may be used. The combined thickness of the additional washers[b] shall not exceed 12 mm.	In addition to the minimum specified washers up to three washers or two washers and one plate washer or one washer and one plate washer or a plate washer may be used. The combined thickness of the additional washers shall not exceed 12 mm.
[a] For preloaded bolting assemblies tightened by the torque control method (including system HRC) only one additional plate washer may be used on the side that is turned. An additional plate washer or additional washer may be placed on the side that is not turned. [b] Washers in accordance with EN 14399–5 or EN 14399–6 as appropriate. Washers to EN 14399–5 shall not be used for assemblies to EN 14399–4 and EN 14399–8.	

If additional washers or plate washers are used, the connection detail should be checked to ensure that the shear plane for bolts with a shank has not been relocated into the threaded portion of the bolt.

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 ≤ 20 mm;

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

8.3 Tightening of non-preloaded bolting assemblies

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 bolting 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.

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 slip-resistant connections shall be specified.

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 17.

Table 17 — Classifications that may be assumed for friction surfaces

Surface treatment	Class [a]	Slip factor μ [b]
Surfaces blasted with shot or grit with loose rust removed, not pitted.	A	0,50
Surfaces hot dip galvanized to EN ISO 1461 and flash (sweep) blasted [c] and with alkali-zinc silicate paint with a nominal thickness of 60 μm [d].	B	0,40
Surfaces blasted with shot or grit: a) coated with alkali-zinc silicate paint with a nominal thickness of 60 μm [d]; b) thermally sprayed with aluminium or zinc or a combination of both to a nominal thickness not exceeding 80 μm.	B	0,40
Surfaces hot dip galvanized to EN ISO 1461 and flash (sweep) blasted (or equivalent abrasion method) [c]	C	0,35
Surfaces cleaned by wire-brushing or flame cleaning, with loose rust removed	C	0,30
Surfaces as rolled	D	0,20

[a] Classes as given in G.6.

[b] The potential loss of preloading force from its initial value is considered in these slip factor values.

[c] Unless alternative equivalent abrasion process capability can be demonstrated, flash (sweep) blasting of hot dip galvanized surfaces shall be carried out according to the procedures and conditions set out in EN 15773. After flash (sweep) blasting the appearance of a matt surface indicates that a soft surface layer of un-alloyed zinc has been removed.

[d] Dry thickness to be within 40 μm to 80 μm range.

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

Otherwise, the slip factor, which shall be determined by test as specified in Annex G, and the contact surfaces shall be prepared in accordance with the tested samples.

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;

c) thick surface coatings should not be present between washers and connected surfaces (see Annex I).

8.5 Tightening of preloaded bolting assemblies

8.5.1 General

Unless otherwise specified, the nominal minimum preloading force $F_{p,C}$ specified in Table 18 shall be taken as:

$$F_{p,C} = 0{,}7\, f_{ub}\, A_s \quad (1)$$

where

f_{ub} is the nominal ultimate strength of the bolt material as defined in EN 1993-1-8

A_s is the stress area of the bolt.

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 boltingassemblies, the tightening method, the tightening parameters and the inspection requirements shall also be specified.

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

Table 18 — Values of the nominal minimum preloading force $F_{p,C}$ in [kN]

Property class	Bolt diameter in mm									
	12	**14**	**16**	**18**	**20**	**22**	**24**	**27**	**30**	**36**
8.8	47	65	88	108	137	170	198	257	314	458
10.9	59	81	110	134	172	212	247	321	393	572

Any of the four tightening methods given in 8.5.3 to 8.5.6 may be used unless restrictions on their use are specified. The *k*-class (as-delivered condition according to EN 14399) of the bolting assembly shall be in accordance with Table 19 for the method used.

Table 19 — *k*-classes for tightening methods

Tightening method	*k*-classes
Torque method (see 8.5.3)	K2
Combined method (see 8.5.4)	K2 or K1
HRC tightening method (see 8.5.5)	K0 with HRD nut only or K2
Direct tension indicator (DTI) method (see 8.5.6)	K2, K1 or K0

For the Torque and HRC tightening methods, the coefficient of variation for the bolting assemblies *k*-factor (V_k according to EN 14399-1) or for the bolt assembly *Fr*-factor (V_{Fr} according to EN 14399-10) shall be ≤ 0,06.

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 otherwise in accordance with EN 14399-2.

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.

Both at the first step and at the final tightening step, 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 (all parts). Each wrench shall be maintained in accordance with EN ISO 6789 (all parts), and in case of pneumatic wrenches checked 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 bolting assemblies 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 bolting assembly has been tightened to the minimum preload (see Table 18) and is later un-tightened, it shall be removed and the whole assembly shall be discarded.

Bolting 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.

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, is considered in the tightening methods specified below except for thick surface coatings. For thick surface coatings, the potential loss of preload may be evaluated using Annex I. In the case of thick surface coatings it shall be specified if additional measures shall be taken to compensate for possible subsequent loss of preloading force.

8.5.2 Torque reference values

For the torque method and the pre-tightening torque of the combined method, the torque reference values $M_{r,i}$ to be used for a nominal minimum preloading force $F_{p,C}$ 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 the EN 14399 series:

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

   2) $M_{r,1} = 0{,}125 \, d \, F_{p,C}$ for *k*-class K1.

b) values determined according to Annex H:

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

8.5.3 Torque method

The bolting assemblies 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 $1/(1 - 1{,}65\ V_k)$ with V_k or $V_{Fr} = 0{,}06$ for *k*-class K2 in combination with the $V_{k.tools}$. See EN 14399–1 for the coefficient of variation V_k and V_{Fr} factors. $V_{k.tools}$ is the coefficient of variation associated with the calibration of tools used in the tightening methodology.

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 0,75 $M_{r,1}$ = 0,094 d $F_{p,C}$ as given in Table 20 may be used, unless otherwise specified;

Table 20 — Torque moment 0,75 $M_{r,1}$ [Nm] for the first step in the combined method

Property class	Bolt diameter in mm									
	12	**14**	**16**	**18**	**20**	**22**	**24**	**27**	**30**	**36**
8.8	53	85	132	182	258	351	446	652	886	1548
10.9	67	106	165	227	322	439	557	815	1107	1935

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 of Table 21, unless otherwise specified.

Table 21 — Additional rotation for the second step in the combined method (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
$t < 2d$	60	1/6
$2d \leq t < 6d$	90	1/4
$6d \leq t \leq 10d$	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 step, the outer socket on the nut rotates clockwise while the inner socket holds the spline end without rotating, the result being that the bolting assembly is progressively tightened by the increasing torque applied to the nut;

— at the last tightening step, 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 bolting 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 bolting assemblies in connections meet the specified minimum preload requirement, the bolting assembly 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 bolting assemblies 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 bolting assembly, e.g. for lack of space, tightening shall be carried out using a procedure in accordance with the torque method (see 8.5.3) with the aid of the k-class K2 information or test according to Annex I, or using a direct tension indicator (see 8.5.6).

8.5.6 Direct tension indicator method

This subclause applies to direct tension indicators in accordance with EN 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 EN 14399-9.

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 bolting assemblies in one connection prior to commencement of the second step.

The second step of tightening shall be as EN 14399-9. The gaps measured on the indicating washer may be averaged to establish the acceptability of the bolting assembly.

8.6 Fit bolts

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 shall not exceed 1/3 of the thickness of the plate (t), unless otherwise specified (see Figure 4).

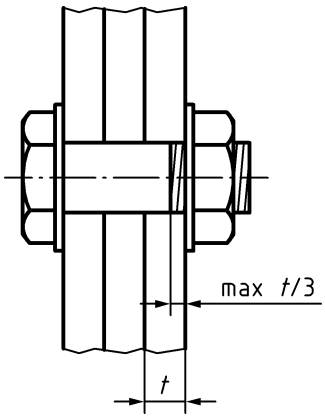


Figure 4 — Threaded portion of the shank in the bearing length for fit bolts

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.

Eccentricity between common holes for the same rivet 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.

The execution specification may specify that the outerfaces of plies shall be free of indentation by the riveting.

If countersunk rivets are specified, 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 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 8.7. 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, or threaded studs.

Such methods shall be used only if 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 resin injection bolts shall be specified.

NOTE 2 Annex J provides information on the supply and use of resin injection bolts.

8.9 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 work hardening rate and hardness (e.g. Grade A4-50/A4-80 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 so that the hardness of the contact surfaces differs by at least 30 HV10, e.g. nitriding or hard chromium plating;

c) anti-galling agents such as PTFE dry film spray;

d) use an anti-galling grade of stainless steel (such as S21800) for one or both of the mating surfaces.

If dissimilar metals or coatings are used, it is necessary to ensure that the required corrosion resistance is obtained.

NOTE The lubrication 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:

— 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;

— profiled steel sheets should not be used to gain access for welding of shear connectors unless the sheets are already secured by suitable fasteners;

— 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

Unless otherwise specified, 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 anchored to a grillage are to be pre-stressed, arrangements shall be made that the bolt has no adhesion to the concrete over its full length.

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.

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 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 masonry.

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 jeopardize the performance of the foundation bolt in service.

9.5.5 Grouting and sealing

If spaces under base plates are to be grouted, fresh material shall be used in accordance with 5.9.

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.

If no grouting is needed, and the edges of the base plate are to be sealed, the method shall be specified.

The concrete and the grouting shall be carried out according to 5.9 and EN 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.

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.

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.

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, EXC3 and EXC4 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

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.

Any site trial erection shall be performed in accordance with the requirements of 6.10.

9.6.5 Erection works

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.

As a guide 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 suitable 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.

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.

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.

Gaps in non-preloaded bolted connections shall conform to 8.3. Prior to preloading, gaps in preloaded bolted connections shall conform to 8.5.1.

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 specified, 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 6.6 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 the requirements for making surfaces, including welded and fabricated surfaces and those where surface imperfections are present, suitable for the application of paints and related products, or metal coating by thermal spraying or hot dip galvanizing. The requirements to take account of the particular coating system to be applied shall be specified.

The detailed requirements for corrosion protection systems, which are specified in the following references and in Annex F, shall be applied as relevant:

a) surfaces to which paint or related products are to be applied: EN ISO 12944 series and Annex F;

b) surfaces to be metal coated by thermal spraying: EN ISO 12679, EN ISO 12670 and Annex F;

c) surfaces to be metal coated by hot dip galvanizing: EN ISO 1461, EN ISO 14713-1, EN ISO 14713-2 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 In general, one year can be considered as a short service lifetime.

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 for paints and related products

These requirements do not apply to products subject to hot dip galvanizing or metal spraying or to stainless steels, except for any requirements relating to the surface cleanness of stainless steels, which shall be specified.

Substrates (i.e. surfaces, welds and edges of steel components) to which paints and related products are to be applied shall be prepared using the methods described in the EN ISO 8504 series.

In terms of cleanliness, roughness and preparation grade, substrates shall be prepared to meet the criteria appropriate to the products that are to be applied. If the expected life of the corrosion protection and corrosivity category are specified, the preparation grade according to EN ISO 8501-3 shall be in accordance with Table 22. If the expected life of the corrosion protection and corrosivity category are not specified, P1 shall apply, unless otherwise specified.

Table 22 — Preparation grade

Expected life of the corrosion protection [a]	Corrosivity category [a]	Preparation grade
> 15 years	C1	P1
	C2 to C3	P2
	Above C3	P2 or P3 as specified
5 years to 15 years	C1 to C3	P1
	Above C3	P2
< 5 years	C1 to C4	P1
	C5 – Im	P2

[a] Expected life of the corrosion protection and corrosivity category are referenced in the EN ISO 12944 series.

Thermally cut surfaces, edges and welds shall be suitably smooth and able to achieve the specified roughness after subsequent surface preparation (see Annex F).

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 it is necessary to ensure that the surface of uncoated weather resistant steels is acceptable visually after weathering, the execution specification shall specify applicable procedures including, as appropriate, those necessary 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).

10.5 Hot dip galvanizing

Guidelines and recommendations on the design, storage and transport of components to be hot dip galvanized are given in EN ISO 14713-2. In particular:

a) if pickling is to be used prior to hot dip 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;

b) if the fabricated component contains enclosed spaces, vent and drain holes shall be provided.

Enclosed spaces shall generally be hot dip galvanized internally and, if not, it shall be specified whether these enclosed spaces shall be sealed after hot dip galvanizing and, if so, with what product.

Residues from previous processes (e.g. paint, oil, grease, welding slag) shall be removed. Unless otherwise specified, blasting prior to hot dip galvanizing is not generally required. If blasting is required, the EN ISO 8503 series may be used to assess the surface roughness.

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 execution 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 imperfections in welds, which are not detectable by visual inspection, can allow water to penetrate the sealed space.

If closed sections are to be hot dip galvanized, they shall not be sealed before hot dip 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 hot dip 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 aesthetic 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 hand/power tool cleaning 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 preloaded 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 midcoat, unless otherwise specified (see F.4).

Unless otherwise specified, 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 or after welding.

If precoated constituent products are to be welded, the methods and extent of repair necessary to the coating shall be specified.

If hot dip 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 hot dip galvanizing for the given corrosivity category (see EN ISO 1461 for additional guidance).

10.10 Cleaning of stainless steel 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.

11 Geometrical tolerances

11.1 Tolerance types

This clause defines the types of geometrical deviations relevant to both functional and structurally essential criteria 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.

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:

c) amended values for functional tolerances already defined;

c) defined parameters and permitted values for the geometrical deviations to be controlled;

e) 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 Annex B. 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.

NOTE EN ISO 5817 also includes geometrical tolerances that apply to the fit-up of weldments.

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 tolerances specified by the relevant product standard. These tolerances continue to apply to components manufactured from such products, unless superseded by more stringent criteria specified in Annex B.

11.2.2.2 Welded sections

Welded components manufactured from plates shall conform to the permitted deviations in Table B.1 and Tables B.3 to B.6.

As an example, 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 B.1.

11.2.2.3 Cold formed sections

Components cold formed by pressing shall conform to the permitted deviations in Table B.2. For components fabricated from rolled cold formed sections, see 11.2.2.1.

As an example, cross sectional tolerances from EN 10162 apply to cold rolled sections whereas Table B.2 applies to sections formed by pressing.

11.2.2.4 Stiffened plating

Stiffened plating shall conform to the permitted deviations in Table B.7.

11.2.2.5 Shells

Shell structures shall conform to the permitted deviations in Table B.11, 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 the ISO 4463 series). If a position point is not established, deviations shall be measured relative to the secondary system.

NOTE ISO 4463-1 refers to the establishment and application of reference systems as follows:

1) The primary system, which normally covers the whole site;

2) The secondary system, which serves as the main reference system or grid for the erection of a particular building;

3) Position points, which mark the location of individual elements, for instance columns.

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.

The execution specification shall specify special tolerances, if these are required, for continuously supported shells (such as flatness or local slope of foundations or other structural supports).

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 B.15, B.17 and B.18.

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:

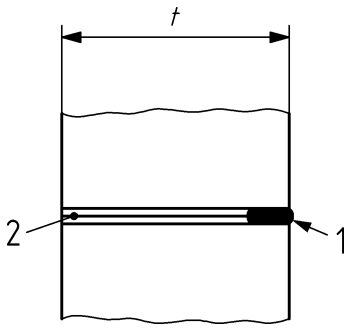
a) the arithmetic average deviation in plan for the inclination of six tied adjacent columns shall conform to the permitted deviations in Table B.15;

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 B.19 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 flats according to EN 10025-2 with a maximum thickness of 3 mm. 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 5.



Key

1 partial penetration butt weld or fillet weld
2 shims

Figure 5 — 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 Annex B. Generally, values for two classes are shown.

Tolerance class 1 shall apply unless the execution specification specifies otherwise. In that case, the execution specification shall specify the tolerance class applicable to individual components or selected parts of an erected structure.

NOTE The decision to invoke tolerance class 2 for part of a structure can be necessary if a glazed facade was to be fitted, for example, in order to reduce the amount of clearance and adjustability required at the interface.

In applying Table B.23, 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:

   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 cases outside of the scope of EN ISO 13920, for a dimension d, a permitted deviation ± Δ 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.

In case of nonconformities with the requirements of this European Standard, each defect may be assessed individually. Such evaluation should be based on the function of the component in which the defect occurs and on the characteristics of the imperfection (type, size, location) in deciding if the defect is either acceptable or shall be repaired.

All inspection and testing shall be undertaken to a predetermined plan with documented procedures.

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 in the component specification.

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 a 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 constituent 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 test results shall be recorded.

12.3 Manufacturing: geometrical dimensions of manufactured components

The inspection and test 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 may be selected, as appropriate, from those listed in ISO 7976-1 and ISO 7976-2. Accuracy may be assessed in accordance with the relevant part of ISO 17123.

The location and frequency of measurements shall be specified in the inspection and test 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:

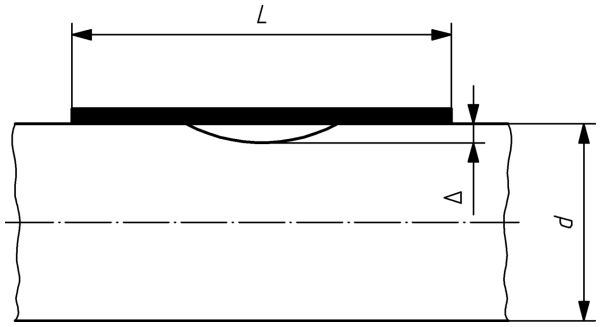
a) if practicable, the nonconformity shall be corrected using methods that are in accordance with this European Standard and checked again;

b) alternatively, the nonconformity shall be evaluated for acceptability according to 12.1;

c) if a) and/or b) is not successful, 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;

d) otherwise the component shall not be used.

Damage resulting in local dents in the surface of hollow sections shall be assessed. The method shown in Figure 6 may be used.



Key

d characteristic cross-sectional dimension of section

L straight edge of length $L \geq 2d$

Δ gap $\Delta \leq$ the larger of $d/100$ or 2 mm

Figure 6 — 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.

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 and test plan.

12.4 Welding

12.4.1 General

Inspection and testing before, during and after welding shall be included in the inspection and test plan according to the requirements given in the relevant part of the EN ISO 3834 series.

The inspection and test plan shall include type testing (see 12.4.2.2), routine inspection and testing (see 12.4.2.3) and project specific inspection and testing (see 12.4.2.4). The inspection and test plan shall identify joints for specific inspection of the fit-up that are likely to present difficulties in achieving the specified fit-up.

Non-destructive testing (NDT) methods shall be selected in accordance with EN ISO 17635 as the basis for the inspection and test plan required by the welding plan.

NDT, with the exception of visual inspection, shall be performed by personnel qualified according to EN ISO 9712.

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. The hold times in Table 23 should also be observed if it is specified that the parent metal adjacent to a weld zone shall be inspected for laminations after welding.

Table 23 — Minimum hold times

		Hold time (hours) [a]	
If preheat is applied in accordance with Method A of EN 1011-2: 2001, Annex C			
Weld size (mm) [b]	**Heat input *Q* (kJ/mm)**	**S275 – S460**	**Above S460**
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	24	48
If preheat is applied in accordance with Method B of EN 1011-2: 2001, Annex C			
Weld size (mm) [b]		**S275 - S690**	**Above S690**
a or s ≤ 20		Cooling period only	24
a or s > 20		24	48

[a] 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.

[b] Size applies to the nominal throat *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 nominal weld throats *a*.

For welds requiring preheat, these periods may be reduced if the weldment is post-heated for a period after welding is complete.

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 Type testing

For the first five joints made to a WPS prepared in accordance with the appropriate part of the EN ISO 15609 series from a new WPQR or a WPQR newly-introduced to the manufacturer the following requirements shall be fulfilled:

a) the quality level B is required for demonstration of the WPS in production conditions;

b) 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. The guidance in EN ISO 17635 should be followed.

NOTE 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 K.

12.4.2.3 Routine inspection and testing

All welds shall be visually inspected throughout their entire length. If surface breaking defects are detected, surface testing by penetrant testing or magnetic particle inspection shall be carried out on the inspected weld.

For EXC1, EXC2 and EXC3 welds, the extent of supplementary NDT is as specified in Table 24.

For EXC4 welds, the scope of supplementary NDT shall be specified with respect to each identified weld.

The extent of NDT covers both testing of surface or internal imperfections if applicable.

The methods to be used for supplementary NDT shall be selected by the appropriate welding coordination personnel from those given in 12.4.2.6.

Once it has been established that production welding according to a WPS meets the quality requirements according to 12.4.2.2, 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 percentage extent of testing (p %) according to Table 24 is defined as a part of an inspection lot according to the following rules, unless otherwise specified:

a) each weld in the inspection lot shall be tested over a length of minimum p % of the individual length. The area to be tested shall be selected at random;

b) if the total length of all the welds in an inspection lot is less than 900 mm, at least one weld shall be tested in its entire length regardless of the p %;

c) if an inspection lot consists of several identical welds with individual length less than 900mm, randomly selected welds with a minimum total length of p % of the total length of all welds in the inspection lot shall be tested in their entire length.

The joints for routine inspection according to Table 24 shall be selected to ensure 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 extent of inspection in Table 24 is related to production welds over a rolling annual basis.

If routine testing of production welds in a given workshop on an annual basis or using electronic methods of monitoring welding parameters demonstrates consistently acceptable quality for welds of a specific type (i.e. joint type, constituent product grade and welding equipment) the extent of routine supplementary NDT in that workshop may be reduced below the percentages given in Table 24 at the discretion of the appropriate welding coordination personnel, provided that a three monthly programme of production audit testing is implemented and documented.

Table 24 —Extent of routine supplementary NDT

Type of weld	Shop and site welds		
	EXC1	EXC2	EXC3 [a]
Transverse butt welds and partial penetration welds in butt joints:	0 % [b]	10 %	20 %
Transverse butt welds and partial penetration welds:			
— in cruciform joints	0 % [b]	10 %	20 %
— in T joints	0 %	5 %	10 %
Transverse fillet welds [c]:			
with a > 12mm or t > 30 mm	0 %	5 %	10 %
with a ≤ 12mm and t ≤ 30 mm	0 %	0 %	5 %
Full penetration longitudinal welds [d] between web and top flange of crane girders	0 %	10 %	20 %
Other longitudinal welds [d], welds to stiffeners and welds specified in the execution specification as being in compression	0 %	0 %	5 %

[a] For EXC4 the percentage extent shall be at least that given for EXC3.

[b] 10 % for such welds executed in steel ≥ S420.

[c] Terms a and t refer respectively to the throat thickness and the thickest material being joined.

[d] Longitudinal welds are those made parallel to the component axis. All others are considered as transverse welds.

The execution specification may identify specific joints for inspection together with the extent and method of testing (see 12.4.2.4). This testing may be counted within the extent of routine testing as appropriate.

If inspection gives non-conforming results, investigation shall be carried out in order to find the reason. The guidance in EN ISO 17635:2016, Annex C should be followed.

12.4.2.4 Project specific inspection and testing

For EXC1, EXC2 and EXC3, the execution specification may identify requirements for production testing and specific joints for inspection together with the extent of testing.

For EXC4 execution specification shall identify specific joints for inspection together with the extent of testing, which shall be that specified for EXC3 as a minimum.

If specified, weld inspection classes (WICs) may be used to classify specific welds for inspection, and in this respect to define the scope and percentage extent of supplementary testing and the test methods to be used according to the criticality of the weld (see Annex L for guidance). If weld inspection classes (WICs) are used, the execution specification shall be used to identify the weld inspection class (WIC) for each relevant weld.

12.4.2.5 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 ISO 17637;

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:

d) for circular sections: the mid-toe, mid-heel and two mid-flank positions;

e) for square or rectangular sections: the four corner positions.

12.4.2.6 Supplementary NDT methods

The following NDT methods shall be carried out in accordance with the general principles given in EN ISO 17635 and with the requirements of the standard particular to each method, such as:

a) penetrant testing (PT) according to EN ISO 3452-1;

b) magnetic particle inspection (MT) according to EN ISO 17638;

c) ultrasonic testing (UT) according to EN ISO 17640 and EN ISO 23279 or EN ISO 13588;

d) radiographic testing (RT) according to the EN ISO 17636 series.

The field of application of NDT methods is specified in their relevant standards.

12.4.2.7 Correction of welds

For EXC2, EXC3 and EXC4, repairs by welding shall be carried out in accordance with the procedures required for production welding.

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.

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 prototype. 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 number of production tests as given in 2) below, 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) the number of locations where production tests for welds connecting deck plates to deck stiffeners: three locations for a deck surface up to a steel deck area of 1 000 m^2 with an additional two test locations for every additional 1 000 m^2 or part thereof up to 5 000 m^2 total area. One test location for every additional 1 000 m^2 (or part thereof) above 5 000 m^2;

3) stiffener-to-stiffener connections with splice plates shall be checked with a production test.

12.4.5 Inspection and testing of welding of reinforcing steel

Inspection and testing of welding of reinforcing steel for composite steel and concrete structures shall be carried out according to EN ISO 17660-1 or EN ISO 17660-2.

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 bolting assemblies shall be checked for fit up after the missing bolting assemblies 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 General

If preloaded bolting assemblies are used for stainless steel connections, the requirements for inspection and testing shall be specified.

12.5.2.2 Inspection of friction surfaces

For slip-resistant connections, the faying 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.

12.5.2.3 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.

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.

12.5.2.4 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 bolting assemblies of the same origin in similar connections with the bolting 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 bolting assemblies inspected overall in a structure shall be as follows:

   1) EXC2: 5 % for the second step of the torque or the combined method and for the DTI method;

   2) 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 bolting 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:

   1) EXC2 and EXC3: sequential type A;

   2) EXC4: sequential type B;

e) the first step shall be checked by visual inspection of connections to ensure they are fully packed;

f) for the inspection of the first step only the under-tightening criterion is to be checked;

g) for final tightening inspection the same bolting assembly shall be used for checking both under-tightening, and, if specified, over-tightening when applying the torque method;

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, corrective actions shall be taken, and after completion re-inspection is required. If the result of

inspection when using a sequential type A is negative, the inspection may be enlarged to the sequential type B.

If fasteners are not applied in accordance with the defined method, the removal and re-installation of the whole bolt group shall be witnessed.

12.5.2.5 Torque method

The inspection of a bolting 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 1,05 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 ± 4 %;

b) the inspection shall be carried out between 12 *h* and 72 *h* after final completion of tightening in the bolt subgroup concerned;

   If the bolting assemblies to be inspected are from different assembly lots, with inspection torque values that are different the locations of each lot shall be established.

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 the required torque.

If a check for over-tightening is specified, the requirements shall be specified. Over-tightened bolting assemblies shall be removed and discarded.

12.5.2.6 Combined method

For EXC3 and EXC4 the first step shall be checked before marking using the same torque conditions as used to reach the 75 % condition. A nut, which turns by more than 15° by the application of the inspecting torque, 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, if necessary by repacking the connection according to 8.5.1 and re-tightening.

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 bolting assembly shall be replaced by new one.

12.5.2.7 HRC method

For EXC2, EXC3 and EXC4 the first tightening step shall be checked by visual inspection of connections to ensure they are fully packed.

The inspection shall be carried out on 100 % of the bolting assemblies by visual inspection. Fully tightened bolting assemblies are identified as those with the spline end sheared off. A bolting 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.

12.5.2.8 Direct tension indicator method

After the first 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 EN 14399-9. The visual inspection shall include a check to identify any indicators that exhibit full compression of the indicator.

If the fasteners are not installed in accordance with EN 14399-9 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 and repairs of solid rivets for hot riveting

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 8.7.3.

Inspection of satisfactory contact shall be 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:

a) EXC2 and EXC3: sequential type A;

b) 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 Special fasteners and fastening methods

12.5.4.1 General

Requirements for inspection of connections using special fasteners or special fastening methods in accordance with 8.8 shall be specified.

If tapped holes are used in cast materials, NDT around the tapped holes shall be carried out to ensure material homogeneity.

12.5.4.2 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 substrates (i.e. surfaces, welds and edges of steel components) shall be visually inspected.

With respect to substrates to which paints or related products are to be subsequently applied, assessment of substrate quality shall be as follows:

a) surface cleanliness shall be assessed according to EN ISO 8501-1 and tested according to the EN ISO 8502 series;

b) surface roughness shall be assessed according to the EN ISO 8503 series;

c) the preparation grade of welds, edges and other areas with surface imperfections shall be assessed according to EN ISO 8501-3.

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. At acceptance of the structure, detailed specific dimensional checks do not need recording unless otherwise specified.

The method selected shall take into account the capability of the survey process in terms of accuracy relative to the acceptance criteria. Cloud point survey methods may be used.

Methods and instruments used may be selected from those listed in ISO 7976-1 and ISO 7976-2.

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.

Corrections may be estimated according to the relevant parts of ISO 17123.

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

On each component, which is to be checked, its erection tolerances shall generally be specified relative to the following reference points:

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 and test plan.

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 and test 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 ISO 3443-3) 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 10088–1 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, options and requirements related to the execution classes

A.1 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 such as “shall be specified” or “the execution specification shall specify” is used).

Table A.1 — Additional information

Clause	Additional information required
4.2 - Constructor's documentation	
4.2.1	Hold-points or requirement to witness inspections or tests, and any consequent access requirements
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 10088–4 or EN 10088-5 for stainless steel Surface finish requirements for other products
5.3.4	Requirements related to the following items: — testing on constituent products; — improved deformation properties perpendicular to the surface; — special delivery conditions of stainless steels; — processing conditions.
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 Technical delivery conditions 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
5.6.7	Steel grade of reinforcing steels
5.6.9.2	Dimensions for taper washers

Clause	Additional information required
5.6.10	Specification for solid rivets for hot riveting
5.6.11	Special fastener not standardized in CEN or ISO standards, as well as any tests necessary
5.9	Grouting materials to be used
5.10	Requirements for type and characteristics of expansion joints
5.11	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
6 – Preparation and assembly	
6.2	Areas where the marking method would not affect the fatigue life Zones where identification marks are not permitted or shall not be visible after completion
6.5.3.1	Location of temperature measurement and test samples for thermally heated zone
6.6.1	Special dimensions for movement joints Nominal hole diameter for solid rivets for hot riveting Dimensions of countersinking
6.9	Special requirements to connections for temporary components, including those related to fatigue
6.10	Requirements for whether, and to what extent, trial assembly is to be used
7 – Welding	
7.4.1.1	Start and stop zones and methods for hollow section joints
7.5.6	Areas where welding of temporary attachments is not permitted The use of temporary attachments for EXC3 and EXC4
7.5.9.1	The location of butt welds used as splices to accommodate available lengths of constituent products
7.5.13	Dimensions of holes for slot and plug welds
7.5.14	Requirements for other weld types
7.5.16	If VT of stray arcs on steel grades < S460 is to be supplemented by PT or MT Requirements for grinding and dressing of the surface of completed welds
7.6.1	Weld quality for identified welds for EXC4
7.6.2	Acceptance criteria in terms of detail category (DC) for welded joint locations subject to fatigue Application of execution requirements given in EN 1993–1–9:2005, Tables 8.1 to 8.8. Application of execution requirements given in EN 1993–2:2006, Annex C.
7.7	The requirements for welding different stainless steel types to each other or to other steels, such as carbon steels
8 – Mechanical fastening	

Clause	Additional information required
8.2.2	Dimensions of bolts in connection utilizing the shear capacity of the unthreaded shank
8.2.4	Whether washers, if required, are to be placed under the nut or the bolt head, whichever is rotated, or both Dimensions and steel grade of plate washers
8.4	Requirements related to contact surfaces in slip resistant connections for stainless steels Area and required class of contact surfaces in preloaded joints
8.8	Requirements and any tests required for use of special fasteners and fastening methods Requirements for use of resin injection bolts
9 – Erection	
9.3.1	Camber and presets required in relation to those provided at manufacturing stage
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
10 – Surface treatment	
10.1	Requirements to take account of the particular coating system to be applied
10.3	If necessary, procedures to ensure that the surface of uncoated weather resistant steels is acceptable visually after weathering 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 Method of sealing wall of sealed enclosed spaces penetrated by fasteners
10.9	Method and extent of repairs to pre-coated constituent products after cutting or welding
10.10	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
11.2.3.2	Special tolerances for continuously supported shells
11.3.2	Tolerance class applicable to each component or parts of a structure
12 – Inspection, testing and corrections	
12.3	Location and frequency of measurements in the inspection and test plan
12.4.2.3	The scope of supplementary NDT for each identified EXC4 weld
12.4.2.4	Specific EXC4 joints for inspection together with the extent of testing
12.5.1	Requirements for checking the installation of an insulation system
12.5.2.1	Requirements for inspection and testing of preloaded bolting assemblies used for stainless steels connections
12.5.4.1	Requirements for inspection of connections using special fasteners or special fastening methods
12.7.1	Requirements for inspection of trial erection
Annex B – Geometrical tolerances	

Clause	Additional information required
B.2	Scope of dimensional checking for dimple measurements (see Table B.11)
Annex C – Check-list for the content of a quality plan	
C.2.3.4	Requirements for keeping records for more than ten years
Annex F – Corrosion protection	
F.1.2	Performance specification for corrosion protection
F.1.3	Prescriptive requirements for corrosion protection
F.4	Requirements for friction surfaces and class of treatment or tests required 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 Requirements for the inspection, checking or qualification of the preparation to be carried out before subsequent overcoating, for hot dip galvanized components
F.7.3	Reference areas for corrosion protection systems in corrosivity categories C3 to C5 and Im1 to Im3
F.7.4	Components for which post-galvanizing inspection is not required Components or specific locations that shall be subjected to additional NDT together with the scope and method to be used

A.2 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 (i.e. where the wording such as “unless otherwise specified” or “shall be specified if” is used).

Table A.2 —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 individual constituent 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 specified
5.3.3	If discontinuities such as cracks, shell and seams are to be repaired
5.3.4	If internal discontinuity quality class S1 for welded cruciform joints If areas close to bearing diaphragms or stiffeners are to be checked for the existence of internal discontinuities

Clause	Option(s) to be specified
5.4	Options for steel castings If other evaluations than testing are required If other acceptance criteria are required
5.5	If other options than those in Table 6 are to be used
5.6.3	If fasteners according to EN ISO 898-1 and EN ISO 898-2 can be used to join stainless steels according toEN 10088-4 or EN 10088-5
5.6.4	If stainless steel bolting assemblies may 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 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 If soft or low stress stamps may be used If soft or low stress stamps may not be used for stainless steels
6.4.3	Other quality requirements to cut surfaces than those of Table 9
6.4.4	If hardness of free edge surfaces is specified for carbon steels If other requirements are specified for the check of the capability of cutting processes
6.5.2	If hot forming of stainless steel is permitted
6.5.3.1	If a documented procedure for flame straightening is required for steel grade S355 and below
6.5.4	Other minimum bending radii for stainless steels to referred grades Other conditions for circular tubes bending by cold forming
6.6.1	Other nominal clearances for bolt or pin diameter less than 12 mm or more than 36 mm Other nominal clearance for normal round holes for applications such as towers and masts If 12 and 14 mm or countersunk bolts may be used in 2 mm clearance holes
6.6.2	Other tolerances on hole diameter
6.6.3	If holes outside of identified limits shall not be formed by punching
6.7	If re-entrant corners or notches may be rounded off with other minimum values of radius. If punched cut outs are not permitted
6.8	If full contact bearing surfaces are required
7 – Welding	
7.2.2	If the conditions for welding cold formed zone according to EN 1993–1–8:2005, 4.14 are not required
7.4.1.1	If special deposition conditions for tack welds are required If work instructions are to be used for EXC1
7.4.1.2	If standard welding procedures may be used for EXC3 or EXC4 (in Table 12) Alternative conditions to testing in accordance with EN ISO 9018

Clause	Option(s) to be specified
7.4.2.2	Alternative qualification procedures for welders of branch connections
7.5.1.1	If cope holes may have a radius less than 40 mm
7.5.4	Other specification than in Annex E for assembly of hollow section components to be welded
7.5.6	If chipping and gouging are permitted on grades ≥ S460 or on components subject to fatigue
7.5.8.2	If end returns on fillet welds are not to be completed
7.5.9.1	For EXC2, if run-on/run-off pieces are required for full penetration transverse butt welds For EXC2, EXC3 and EXC4, if run-on/run-off pieces are required for full penetration longitudinal butt welds or partial penetration butt welds If a flush surface is required
7.5.9.2	If permanent steel backing material are not to be used for single side welds 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
7.5.16	If, for steel grades ≥ S460, removing of weld spatter is not required.
7.6.1	If, for EXC1, EXC2 and EXC3, other acceptance criteria for weld imperfections are required
7.6.2	Alternative criteria if acceptance criteria for welds subject to fatigue are not to be specified in terms of detail category (DC) If acceptance criteria to Annex C of EN ISO 5817:2014 are to be used
7.6.3	Requirements for welds in orthotropic bridge decks
8 – Mechanical fastening	
8.2.1	If, in addition to tightening, other measures or means are to be used to secure the nuts If preloaded assemblies require additional locking devices 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 If washers are not required under both the bolt head and the nut for single lap connections with only one bolt row If plate washers are not required for connections with slotted and oversized holes
8.3	If full contact bearing is specified
8.5.1	Other nominal minimum preloading force value together with the relevant bolting assemblies, tightening method, tightening parameters and inspection requirements If a lower level of preload is required If there are restrictions on use of any of the tightening methods given in Table 19 If calibration to Annex H for the torque method is permitted If additional measures are to be taken to offset possible subsequent loss of preloading force
8.5.4	If other values than those given in Table 20 are specified

Clause	Option(s) to be specified
	If other values than those given in Table 21 are required for the second step
8.5.5	If the first step of HRC method 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 required
8.7.3	If outer faces of plies are to be free of indentation by the riveting machine
9 – Erection	
9.4.1	If site measurements for the works shall be related to other system than the system established for the setting out and measurement of the construction works
9.5.3	If compensation for settlement of supports is not acceptable
9.5.4	If packings subsequently to be grouted, may be placed so that the grout does not totally enclose them If packings for bridges may be left in position If levelling nuts on the foundation bolts under the base plate are to be removed
9.5.5	If tamping and ramming against properly fixed supports are to be used 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 is to be different from flat steel If drifts may not be used to align connections
10 – Surface treatment	
10.2	If there are requirements for surface cleanliness of stainless steels If a preparation grade other than P1 is to apply If preparation grade P2 or P3 are to be used for corrosion category above C3 and expected life of the corrosion protection longer than 15 years
10.5	If enclosed spaces are to be sealed after hot dip galvanizing and, if so, with what product If blasting prior to hot dip galvanizing is required, and the requirements if so
10.6	If weld imperfections permitted under the execution specification require sealing by application of suitable filler material to prevent the ingress of moisture 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 are to be treated with other than primer and midcoat If bolted connections including the perimeter around such connections are to be treated with other than 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

Clause	Option(s) to be specified
11 – Geometrical tolerances	
11.1	If special tolerances are required
11.2.3.5	If shims may not be used to reduce the gap of bolt splices in full contact bearing
11.3.1	If the alternative criteria for functional tolerances in 11.3.3 apply
11.3.2	Individual components or selected parts of an erected structure to which tolerance class 2 applies
11.3.3	If specified alternative criteria are to 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
12.4.2.1	If parent metal is to be inspected for laminations after welding
12.4.2.3	If other rules are required for definition of the percentage extent of testing
12.4.2.4	If specific joints are identified for inspection together with the extent and method of testing for EXC1, EXC2 and EXC3 If weld inspection classes are to be used for defining the scope and percentage extent of supplementary, and, if so, the weld inspection class for each relevant weld
12.4.4	If production tests are required for EXC3 and EXC4
12.5.2.4	Other inspection method than sequential sampling plan in Annex M If checking of over-tightening is required for the torque method
12.5.2.5	If a check for over-tightening using the torque method is required and, if so, the requirements for the check
12.7.3.1	If detailed specific dimensional checks at acceptance are required
12.7.3.4	Extent of measurements for the survey of geometrical position of connection nodes if other than site interconnection nodes Conditions of measurements other than under the self-weight of steelwork
12.7.3.6	An envelope of permissible positions if significant movement of a structure is anticipated that could affect dimensional checking
12.7.4	Tolerance range on the load, if components of a structure are to be erected to a specific load
Annex D – Procedure for checking capability of automated thermal cutting processes	
D.1	If the verification of the quality of the cut surfaces shall not be done under the authority of the responsible welding coordinator
Annex E – Welded joints in hollow sections	
E.4(d)	If the hidden toe area is not to be welded

Clause	Option(s) to be specified
Annex F – Corrosion protection	
F.1.2	If a performance specification is to be used
F.2.2	Other requirements than the EN ISO 8501 series and EN ISO 1461 for surface preparation of carbon steels
F.5	If the lower embedded part of foundation bolts are not to be left untreated
F.7.2	Other requirements for the extent of checking required for paint treatment
F.7.3	If reference areas are not to be specified for corrosion protection systems in Corrosivity Categories C3 to C5 and Im1 to Im3
F.7.4	If hot dip galvanized components are not subjected to post-galvanizing inspection (LMAC)
Annex G – Determination of slip factor	
G.5	If the design life of the structure is other than 50 years
G.6	If extended creep testing is required
Annex I – Determination of loss of preload for thick surface coating	
I.1	Preloads form bolting assemblies tightened that are to be tightened and re-tightened by the torque method (see Table I.1)

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 with [PC] 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 identified with [PS] generally demand the selection of the appropriate execution class on a component–by-component or a connection detail-by-detail project specific 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 [PC]	Nr	Yes	Yes	Yes
5 – Constituent products				
5.2 Identification, inspection documents and traceability				
Traceability [PC]	Nr	Yes (by marking)	Yes (from receipt to handover)	Yes (from receipt to handover)
Marking [PC]	Nr	Yes	Yes	Yes

Clauses	EXC1	EXC2	EXC3	EXC4
6 – Preparation and assembly				
6.4 Cutting				
6.4.3 Thermal cutting [PC]	See Table 9	See Table 9	See Table 9	See Table 9
7 – Welding				
7.1 General				
7.1 General [PC]	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				
7.4.1.1 General [PC]	Appropriate work instructions (if specified to be used)	See EN ISO 3834-3	See EN ISO 3834-2	See EN ISO 3834-2
7.4.1.2 Qualification of welding procedures [PC]	Nr	See Table 12	See Table 12	See Table 12
7.4.2.1 Welding and welding operators [PC]	Revalidation frequency specified	See EN ISO 3834-3	See EN ISO 3834-2	See EN ISO 3834-2
7.4.3 Welding coordination [PC]	Sufficient supervision	Technical knowledge according Tables 14 or 15	Technical knowledge according Tables 14 or 15	Technical knowledge according Tables 14 or 15
7.5 Preparation and execution of welding				
7.5.1 Joint preparation				
7.5.1.1 General [PC]	Nr	Prefabrication primers not allowed unless tested	Prefabrication primers not allowed unless tested	Prefabrication primers not allowed unless tested
7.5.6 Temporary attachments [PS]	Nr	Nr	Restrictions on use may be specified	Restrictions on use may be specified
7.5.7 Tack welds [PC]	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 [PC]	Nr	Run on/run off pieces for full penetration transverse butt welds (if specified) Run-on/run-off pieces for full penetration longitudinal butt welds or partial penetration butt welds (if specified)	Run on/run off pieces for full penetration transverse butt welds Run-on/run-off pieces for full penetration longitudinal butt welds or partial penetration butt welds (if specified)	Run on/run off pieces for full penetration transverse butt welds Run-on/run-off pieces for full penetration longitudinal butt welds or partial penetration butt welds (if specified)
7.5.9.2 Single sided welds [PC]	Nr	Nr	Permanent backing continuous	Permanent backing continuous
7.6 Acceptance criteria				
7.6.1 Routine requirements [PC] [PS for EXC4]	EN ISO 5817 Quality level D generally	EN ISO 5817 Quality level C generally	EN ISO 5817 Quality level B	EN ISO 5817, EXC3 as a minimum with specific criteria for identified welds
7.6.2 Fatigue requirements [PC]	Not applicable	EN ISO 5817:2014, Annex C (if specified to be used)	EN ISO 5817:2014, Annex C (if specified to be used)	EN ISO 5817:2014, Annex C (if specified to be used)
9 – Erection				
9.6 Erection and work at site				
9.6.3 Handling and storage on site [PC]	Nr	Documented restoration procedure	Documented restoration procedure	Documented restoration procedure
12 – Inspection, testing and repair				
12.4 Welding				
12.4.2 Inspection after welding				
12.4.2.3 Routine inspection [PC]	NDT: See Table 24	NDT: See Table 24	NDT: See Table 24	NDT: EXC3 to Table 24 as a minimum
12.4.2.4 Project specific inspection [PS]	See Table A.2	See Table A.2	See Table A.2	Identified joints for inspection together with the extent of testing
12.4.2.7 Correction of welds [PC]	Nr	According to WPS	According to WPS	According to WPS

Clauses	EXC1	EXC2	EXC3	EXC4
12.5 Mechanical fastening				
12.5.2 Inspection and testing of preloaded bolted connections				
12.5.2.3 Before tightening [PC]	Nr	Checking of tightening procedure	Checking of tightening procedure	Checking of tightening procedure
12.5.2.4 During and after tightening [PC]	Nr	5 % of second tightening step using Sequential type A (unless otherwise specified)	5 % of first tightening step and 10 % of second tightening step using Sequential type A (unless otherwise specified)	5 % of first tightening step and 10 % of second tightening step using Sequential type B (unless otherwise specified)
12.5.2.5 Torque method [PC]	Nr	See Table 25	See Table 25	See Table 25
12.5.2.6 Combined method [PC]	Nr for check of first tightening step	Nr for check of first tightening step	Check of first tightening step before marking	Check of first tightening step before marking
12.5.2.7 HRC method [PC]	Nr	Inspection of first tightening step	Inspection of first tightening step	Inspection of first tightening step
12.5.3.1 Inspection, testing and repair of solid rivets for hot riveting [PC]	Nr	Ring test Sequential type A	Ring test Sequential type A	Ring test Sequential type B
12.7 Erection				
12.7.3.1 Survey of the geometrical position of connection nodes [PC]	Nr	Nr	Record of the survey	Record of the survey

Annex B
(normative)

Geometrical tolerances

B.1 General

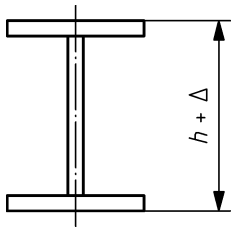
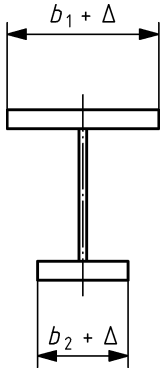
Permitted deviations for essential and functional manufacturing tolerances are tabulated in Tables B.1 to B.14.

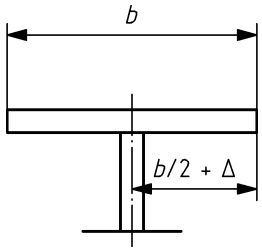
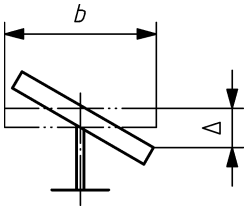
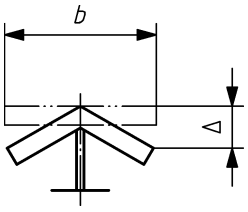
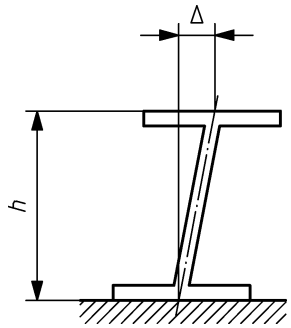
Permitted deviations for essential and functional erection tolerances are tabulated in Tables B.15 to B.25.

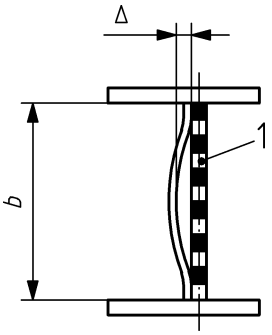
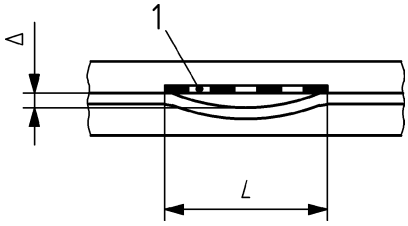
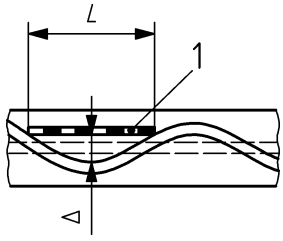
NOTE See prEN 1090–4 for the manufacturing tolerances for cold formed profile sheets and the erection tolerances for profiled steel sheeting.

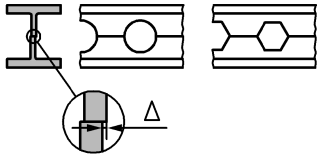
B.2 Manufacturing tolerances

Table B.1 — Manufacturing tolerances - Welded profiles

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
1	Depth 	Overall depth h: $h \leq 900$ mm $900 < h \leq 1800$ mm $h > 1800$ mm	- Δ = h /50 (note negative sign)	Δ = ± 3 mm Δ = ± h /300 Δ = ± 6 mm	Δ = ± 2 mm Δ = ± h /450 Δ = ± 4 mm
2	Flange width: 	Width $b = b_1$ or b_2:	- Δ = b /100 (note negative sign)	+ Δ = b /100 but |Δ| ≥ 3 mm	+ Δ = b /100 but |Δ| ≥ 2 mm

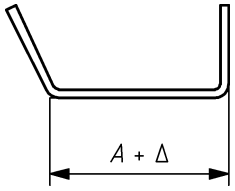
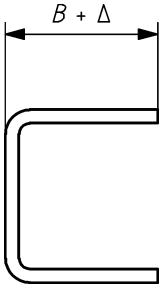
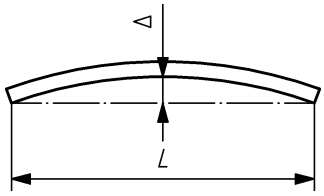
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
3	Web eccentricity: 	Position of web: — general case: — flange parts in contact with structural bearings:	No requirement	 Δ = ± 5 mm Δ = ± 3 mm	 Δ = ± 4 mm Δ = ± 2 mm
4	Squareness of flanges: 	Out of squareness: — general case: — flange parts in contact with structural bearings:	No requirement	 Δ = ± *b* /100 but |Δ| ≥ 5 mm Δ = ± *b* /400	 Δ = ± *b* /100 but |Δ| ≥ 3 mm Δ = ± *b* /400
5	Flatness of flanges: 	Out of flatness: — general case: — flange parts in contact with structural bearings:	No requirement	 Δ = ± *b* /150 but |Δ| ≥ 3 mm Δ = ± *b* /400	 Δ = ± *b* /150 but |Δ| ≥ 2 mm Δ = ± *b* /400
6	Squareness at bearings: 	Verticality of web at supports, for components without bearing stiffeners:	Δ = ± *h* /200 but |Δ| ≥ t_w (t_w = web thickness)	Δ = ± *h* /300 but |Δ| ≥ 3 mm	Δ = ± *h* /500 but |Δ| ≥ 2 mm

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
7	Plate curvature:  	Deviation Δ over plate height b:	$\Delta = \pm b/200$ if $b/t \leq 80$ $\Delta = \pm b^2/(16\,000\,t)$ if $80 < b/t \leq 200$ $\Delta = \pm b/80$ if $b/t > 200$ but $\lvert\Delta\rvert \geq t$ (t = plate thickness)	$\Delta = \pm b/100$ but $\lvert\Delta\rvert \geq 5$ mm	$\Delta = \pm b/150$ but $\lvert\Delta\rvert \geq 3$ mm
8	Web distortion:  	Deviation Δ on gauge length L equal to web height b (see (7)): NOTE For components that are tapered or have variable web height b the permitted deviation is related to the mean web height at the location of the gauge.	$\Delta = \pm b/100$ but $\lvert\Delta\rvert \geq t$ (t = plate thickness)	$\Delta = \pm b/100$ but $\lvert\Delta\rvert \geq 5$ mm	$\Delta = \pm b/150$ but $\lvert\Delta\rvert \geq 3$ mm
9	Web undulation:  	Deviation Δ on gauge length L equal to web height b (see (7)): NOTE For components that are tapered or have variable web height b the permitted deviation is related to the mean web height at the location of the gauge.	$\Delta = \pm b/100$ but $\lvert\Delta\rvert \geq t$ (t = plate thickness)	$\Delta = \pm b/100$ but $\lvert\Delta\rvert \geq 5$ mm	$\Delta = \pm b/150$ but $\lvert\Delta\rvert \geq 3$ mm

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
10	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 $r = D/2 \geq 200$ mm	No requirement	 Δ = 2 mm Δ = 2 mm Δ = *r*/100 and Δ ≤ 5 mm	 Δ = 2 mm Δ = 2 mm Δ = *r*/100 and Δ ≤ 5 mm

Key:
1 gauge length
NOTE Notations such as Δ = ± *d* /100 but |Δ| ≥ *t* mean that |Δ| is the *larger* of *d* /100 and *t*.

Table B.2 — Manufacturing tolerances - Press braked profiles

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
1	Internal element width:  	Width A between bends (component of thickness t): t < 3 mm: Length < 7 m Length ≥ 7 m t ≥ 3 mm: Length < 7 m Length ≥ 7 m	- Δ = A /50 (note negative sign)	 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 (component of thickness t): Mill edge: t < 3 mm t ≥ 3 mm Sheared edge: t < 3 mm t ≥ 3 mm	- Δ = B /80 (note negative sign)	 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	Straightness for component to be used unrestrained:  	Deviation Δ from straightness:	Δ = ± L /1000	No requirement	No requirement

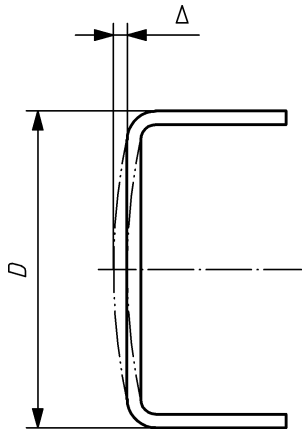
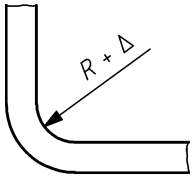
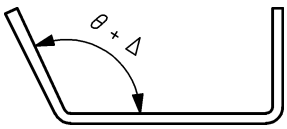
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
4	Flatness: 	Convexity or concavity:	No requirement	$\Delta = \pm D/50$	$\Delta = \pm D/100$
5	Bend radius: 	Internal bend radius *R:*	No requirement	Δ = ± 2 mm	Δ = ± 1 mm
6	Shape: 	Angle θ between adjacent components:	No requirement	Δ = ± 3°	Δ = ± 2°

Table B.3 — Manufacturing tolerances - Flanges of welded profiles

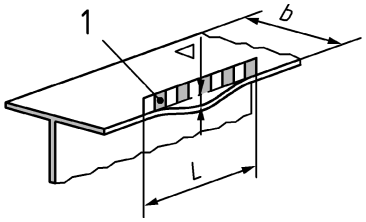
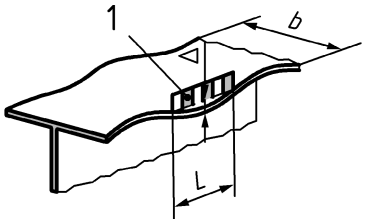
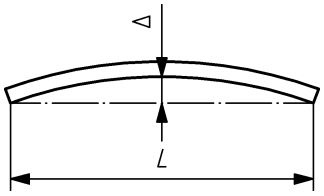
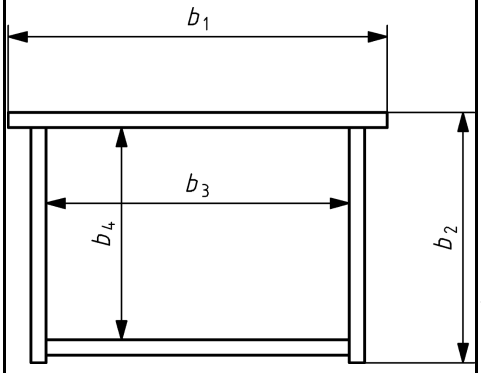
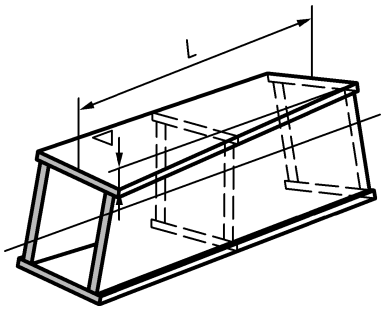
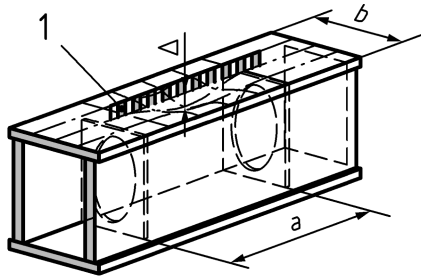
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
1	Flange distortion of I section:  Key 1 gauge length	Deviation Δ on gauge length L where L = flange width b:	$\Delta = \pm b/150$ if $b/t \leq 20$ $\Delta = \pm b^2/(3000\ t)$ if $b/t > 20$ t = flange thickness	$\Delta = \pm b/100$	$\Delta = \pm b/150$
2	Flange undulation of I section:  Key 1 gauge length	Deviation Δ on gauge length L where L = flange width b:	$\Delta = \pm b/150$ if $b/t \leq 20$ $\Delta = \pm b^2/(3000\ t)$ if $b/t > 20$ t = flange thickness	$\Delta = \pm b/100$	$\Delta = \pm b/150$
3	Straightness for component to be used unrestrained:  	Deviation Δ from straightness:	$\Delta = \pm L/1000$	$\Delta = \pm L/1000$	$\Delta = \pm L/1000$

Table B.4 — Manufacturing tolerances - Flanges of welded box sections

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
1	Section dimensions:  	Deviation in internal or external dimensions: b < 900 mm 900 mm ≤ b < 1800 mm b ≥ 1800 mm where: $b = b_1, b_2, b_3$ or b_4	$-\Delta = b/100$ (note negative sign)	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:	No requirement	Δ = ± L /700 but |Δ| ≥ 4 mm and |Δ| ≤ 10 mm	Δ = ± L /1000 but |Δ| ≥ 3 mm and |Δ| ≤ 8 mm
3	Out of plane imperfections of plate panels between webs or stiffeners, general case:  Key: 1 straight edge gauge of length L	Deviation Δ perpendicular to the plane of the plate: if $a \le 2b$: $L = a$ if $a > 2b$: $L = 2b$	Δ = ± a/250 Δ = ± b/125	Δ = ± a/250 Δ = ± b/125	Δ = ± a/250 Δ = ± b/125

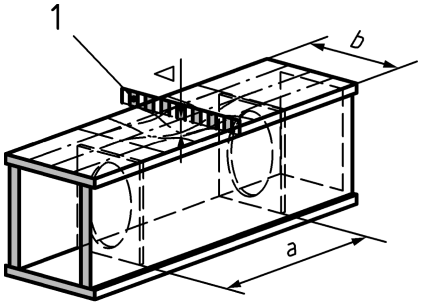
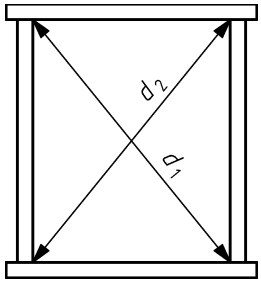
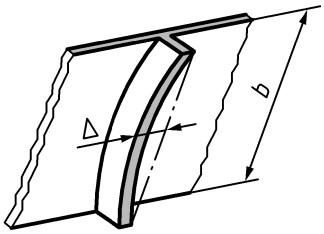
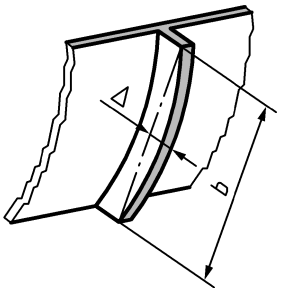
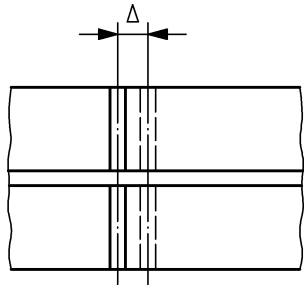
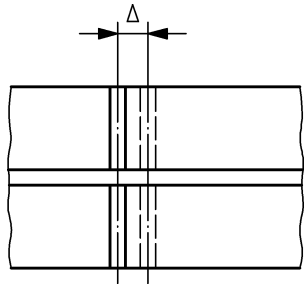
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
4	Out of plane imperfections of plate panels between webs or stiffeners (special case with compression in the transverse direction – the general case applies unless this special case is specified):  Key: 1 straight edge gauge of length L	Deviation Δ perpendicular to the plane of the plate: if $b \le 2a$: $L = b$ if $b > 2a$: $L = 2a$	$\Delta = \pm b/250$ $\Delta = \pm a/125$	$\Delta = \pm b/250$ $\Delta = \pm a/125$	$\Delta = \pm b/250$ $\Delta = \pm a/125$
5	Squareness:  $(d_1+d_2)_{act} = (d_1+d_2)$ actual $(d_1+d_2)_{nom} = (d_1+d_2)$ nominal	Difference Δ between diagonal dimensions at diaphragm positions: $\Delta = \lvert(d_1 - d_2)_{act} - (d_1 - d_2)_{nom}\rvert$ (hence $\Delta = \lvert d_1 - d_2\rvert_{act}$ if d_1 and d_2 are nominally the same)	No requirement	$\Delta = \frac{(d_1+d_2)_{nom}}{400}$ but $\lvert\Delta\rvert \ge 6$ mm	$\Delta = \frac{(d_1+d_2)_{nom}}{600}$ but $\lvert\Delta\rvert \ge 4$ mm

Table B.5 — Manufacturing tolerances - Web stiffeners and cruciform joints of profiles or box sections

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
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	$\Delta = \pm b/250$ but $\lvert\Delta\rvert \geq 4$ mm	$\Delta = \pm b/375$ but $\lvert\Delta\rvert \geq 2$ 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	$\Delta = \pm b/500$ but $\lvert\Delta\rvert \geq 4$ mm	$\Delta = \pm b/750$ but $\lvert\Delta\rvert \geq 2$ mm
3	Location of web stiffeners: 	Distance from intended location:	$\Delta = \pm 5$ mm	$\Delta = \pm 5$ mm	$\Delta = \pm 3$ mm
4	Location of web stiffeners at support: 	Distance from intended location:	$\Delta = \pm 3$ mm	$\Delta = \pm 3$ mm	$\Delta = \pm 2$ mm

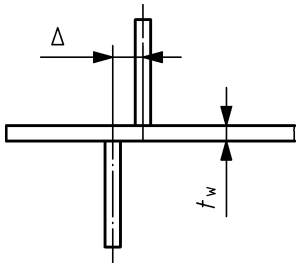
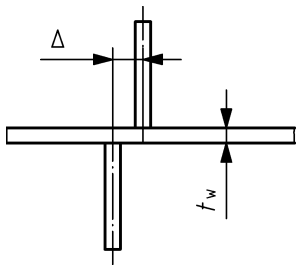
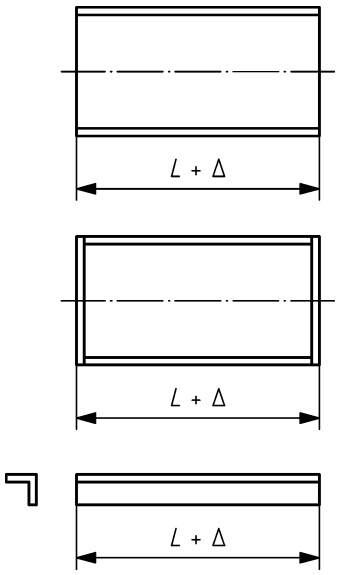
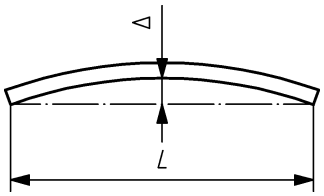
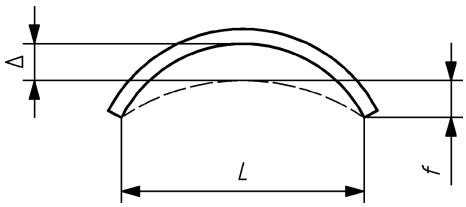
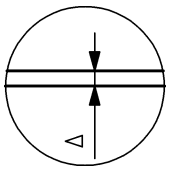
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
5	Eccentricity of web stiffeners: 	Eccentricity between a pair of stiffeners: NOTE For cruciform joints the misalignment eccentricity is limited to ± t /2 where t is the larger of the thicknesses of the two plates attached either side of the web, see Table B.21 (10) and (11).	$\Delta = \pm t_w/2$	$\Delta = \pm t_w/2$	$\Delta = \pm t_w/3$
6	Eccentricity of web stiffeners at supports: 	Eccentricity between a pair of stiffeners: NOTE For cruciform joints the misalignment eccentricity is limited to ± t /2 where t is the larger of the thicknesses of the two plates attached either side of the web, see Table B.21 (10) and (11).	$\Delta = \pm t_w/3$	$\Delta = \pm t_w/3$	$\Delta = \pm t_w/4$
NOTE Notations such as $\Delta = \pm d/100$ but $\lvert\Delta\rvert \geq 5$ mm mean that $\lvert\Delta\rvert$ is the *larger* of d /100 and 5 mm.					

Table B.6 — Manufacturing tolerances - Components

No	Criterion	Parameter	Functional tolerances [a] 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.	$\Delta = \pm (L/5000 + 2)$ mm $\Delta = \pm 1$ mm	$\Delta = \pm (L/10000 + 2)$ mm $\Delta = \pm 1$ mm
2	Length, where sufficient compensation with adjacent component is possible:	Cut length measured on centreline:	$\Delta = \pm 50$ mm	$\Delta = \pm 50$ mm
3	Straightness: 	Deviation Δ from rectangular axes of a fabricated or press braked section:	$\Delta = \pm L/1000$ but $\lvert\Delta\rvert \geq 5$ mm	$\Delta = \pm L/1000$ but $\lvert\Delta\rvert \geq 3$ 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.	$\Delta = \pm L/500$ but $\lvert\Delta\rvert \geq 6$ mm	$\Delta = \pm L/1000$ but $\lvert\Delta\rvert \geq 4$ 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.

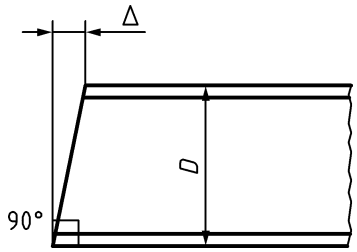
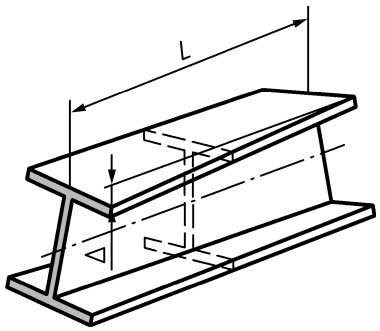
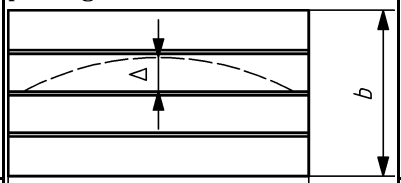
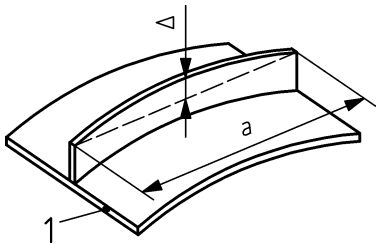
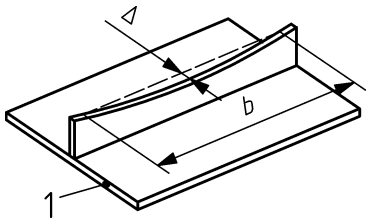
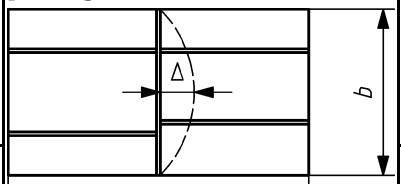
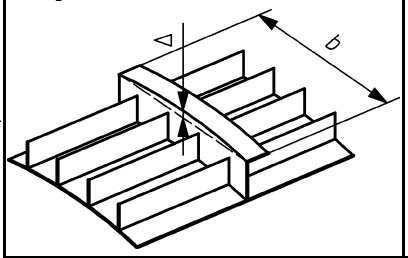
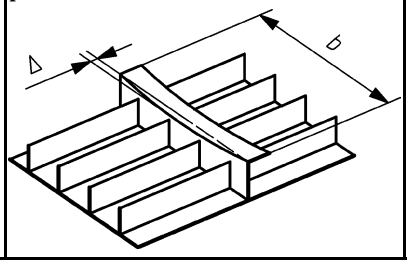
No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ	
			Class 1	**Class 2**
6	Squareness of ends:  	Squareness to longitudinal axis: - ends intended for full contact bearing: - ends not intended for full contact bearing:	$\Delta = \pm D/1000$ $\Delta = \pm D/100$	$\Delta = \pm D/1000$ $\Delta = \pm D/300$ but $\lvert\Delta\rvert \leq 10$ mm
7	Twist:  	Overall deviation Δ in a piece of length L: NOTE For box sections, see Table B.4.	$\Delta = \pm L/700$ but $\lvert\Delta\rvert \geq 4$ mm and $\lvert\Delta\rvert \leq 20$ mm	$\Delta = \pm L/1000$ but $\lvert\Delta\rvert \geq 3$ mm and $\lvert\Delta\rvert \leq 15$ mm
a No essential tolerance specified.				
NOTE Notations such as $\Delta = \pm d/100$ but $\lvert\Delta\rvert \geq 5$ mm mean that $\lvert\Delta\rvert$ is the *larger* of $d/100$ and 5 mm.				

Table B.7 — Manufacturing tolerances - Stiffened plating

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
1	Straightness of stiffeners: Longitudinal stiffeners in longitudinally stiffened plating:  Key: 1 plate	Deviation Δ perpendicular to the plate:  	$\Delta = \pm a/400$	$\Delta = \pm a$ /400	$\Delta = \pm a$ /750 but $\lvert\Delta\rvert \geq 2$ mm
2		Deviation Δ parallel to the plate measured relative to a gauge length equal to the width b of the plating:  	$\Delta = \pm b$ /400	$\Delta = \pm b$ /400	$\Delta = \pm b$ /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: $\Delta = \pm a$ /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	$\Delta = \pm b$ /400	$\Delta = \pm b$ /500

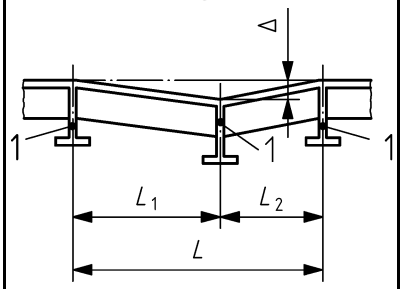
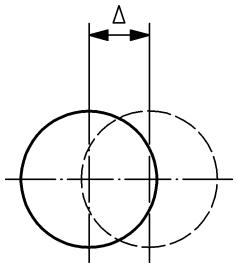
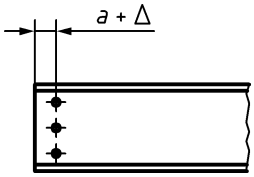
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
5	Levels of cross members in stiffened plating:  Key: 1 cross member	Level relative to the adjacent cross frames:	$\Delta = \pm L/400$	$\Delta = \pm L/400$	$\Delta = \pm L/500$ but $\lvert\Delta\rvert \geq 3$ mm

Table B.8 — Manufacturing tolerances - Fastener holes, notches and cut edges

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	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:	$\Delta = \pm 2$ mm	$\Delta = \pm 2$ mm	$\Delta = \pm 1$ mm
2	Position of holes for fasteners:  	Deviation Δ in distance a between an individual hole of diameter d_0 and a cut end: if $a < 3\ d_0$ if $a \geq 3\ d_0$	- Δ = 0 (note negative sign) $\Delta = \pm 3$ mm	- Δ = 0 + Δ = 3 mm $\Delta = \pm 3$ mm	- Δ = 0 + Δ = 2 mm $\Delta = \pm 2$ mm

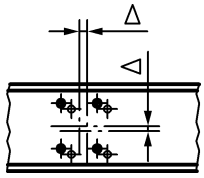
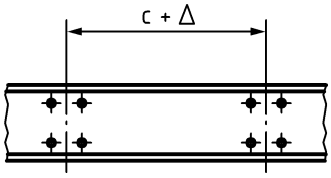
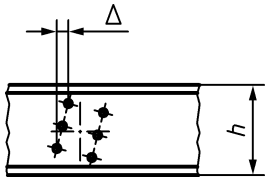
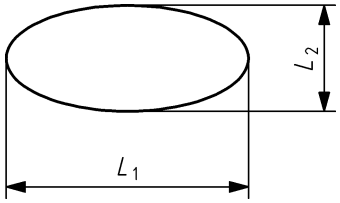
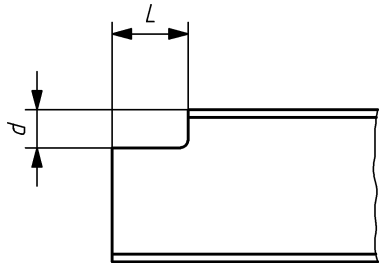
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
3	Position of hole group: 	Deviation Δ of a hole group from its intended position:	Δ = ± 2 mm	Δ = ± 2 mm	Δ = ± 1 mm
4	Spacing of hole groups: 	Deviation Δ in spacing *c* between centres of hole groups: - general case: - where a single piece is connected by two groups of fasteners:	No requirement	Δ = ± 5 mm Δ = ± 2 mm	Δ = ± 2 mm Δ = ± 1 mm
5	Twist of a hole group: 	Twist Δ: if $h \leq 1000$ mm if $h > 1000$ mm	No requirement	Δ = ± 2 mm Δ = ± 4 mm	Δ = ± 1 mm Δ = ± 2 mm
6	Ovalisation of holes: 	$\Delta = L_1 - L_2$	No requirement	Δ = ± 1 mm	Δ = ± 0,5 mm
7	Notches: 	Deviation Δ of notch depth and length: depth *d* length *L*	No requirement	- Δ = 0 mm + Δ ≤ 3 mm - Δ = 0 mm + Δ ≤ 3 mm	- Δ = 0 mm + Δ ≤ 2 mm - Δ = 0 mm + Δ ≤ 2 mm

Table B.9 — Manufacturing tolerances - Crane beams

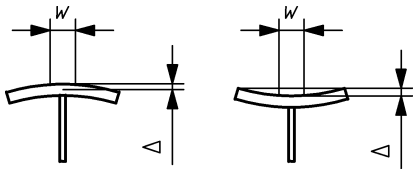
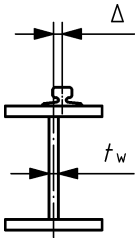
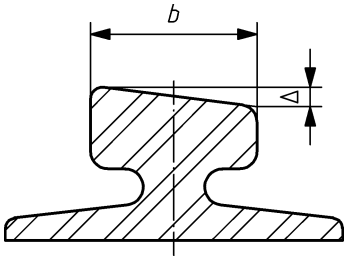
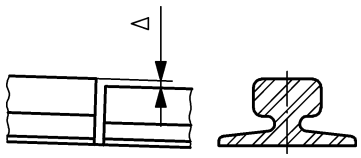
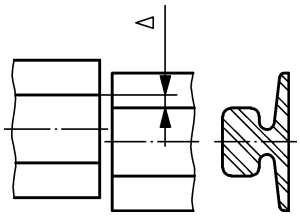
No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ	
			Class 1	Class 2
1	Flatness of top flange of a crane beam: 	Out of flatness over a central width w equal to the rail width plus 10 mm either side of rail in nominal position:	Δ = ± 1 mm	Δ = ± 1 mm
2	Eccentricity of rail relative to web: 	For $t_w \leq 10$ mm For $t_w > 10$ mm	Δ = 5 mm Δ = 0,5 t_w	Δ = 5 mm Δ = 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
a No essential tolerance specified				

Table B.10 — Manufacturing tolerances - Column splices and baseplates

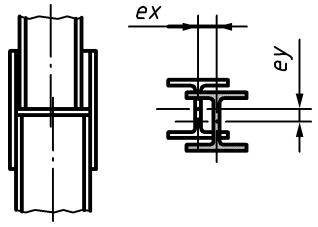
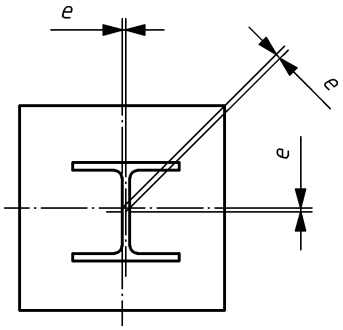
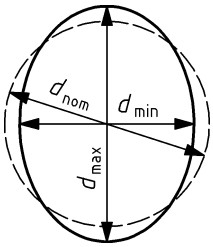
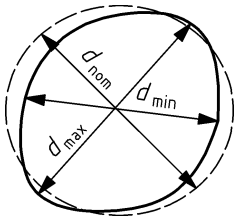
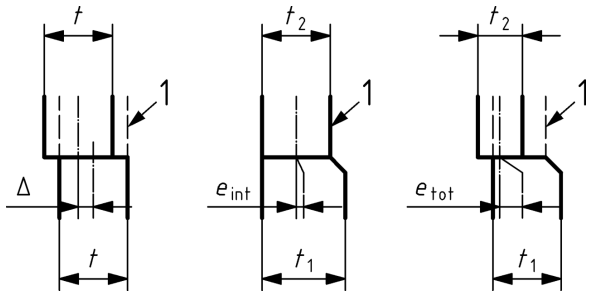
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
1	Column splice: 	Non-intended eccentricity *e* about either axis:	No requirement	5 mm	3 mm
2	Baseplate: 	Non-intended eccentricity *e* in any direction:	No requirement	5 mm	3 mm

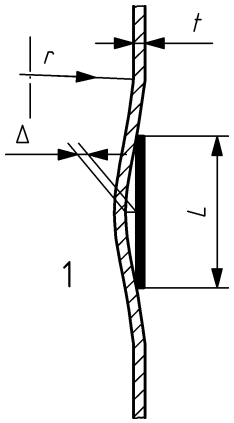
Table B.11 — Manufacturing tolerances - Cylindrical and conical shells

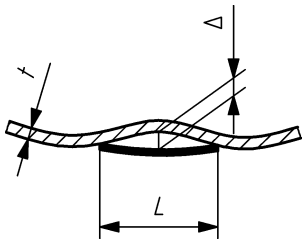
<table>
<tr><th>No</th><th colspan="5">Criteria and details</th></tr>
<tr><td rowspan="8">1</td><td rowspan="8">Out-of-roundness:
 

a) flattening
 

b) unsymmetrical</td><td colspan="4">Difference between the maximum and minimum values of the measured internal diameter, relative to the nominal internal diameter:
$\Delta = \frac{1000\left(d_{max} - d_{min}\right)}{d_{nom}}$</td></tr>
<tr><td colspan="4">Essential tolerances [a]</td></tr>
<tr><td></td><td colspan="3">Permitted deviation Δ</td></tr>
<tr><td>Diameter</td><td>$d \le 0{,}50$ m</td><td>0,50 m < d < 1,25 m</td><td>$d \ge 1{,}25$ m</td></tr>
<tr><td>Class A</td><td>$\Delta = 14$</td><td>$\Delta = 7 + 9{,}3\ (1{,}25 - d)]$</td><td>$\Delta = 7$</td></tr>
<tr><td>Class B</td><td>$\Delta = 20$</td><td>$\Delta = 10 + 13{,}3\ (1{,}25 - d)]$</td><td>$\Delta = 10$</td></tr>
<tr><td>Class C</td><td>$\Delta = 30$</td><td>$\Delta = 15 + 20{,}0\ (1{,}25 - d)]$</td><td>$\Delta = 15$</td></tr>
<tr><td colspan="4">NOTE d is the nominal internal diameter d_{nom} in metres.</td></tr>
<tr><td rowspan="5">2</td><td colspan="3" rowspan="5">Misalignment of plates:
Non-intended (accidental) eccentricity at joints perpendicular to membrane compressive forces
At a change of plate thickness, the intentional part of the eccentricity is not included.
 

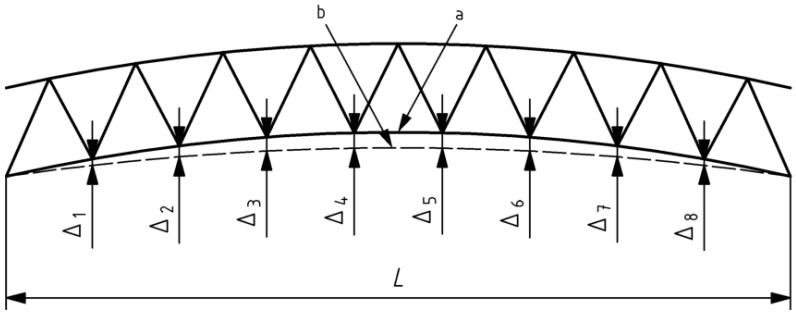
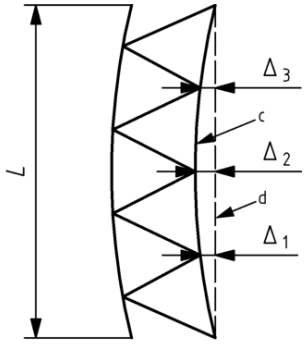
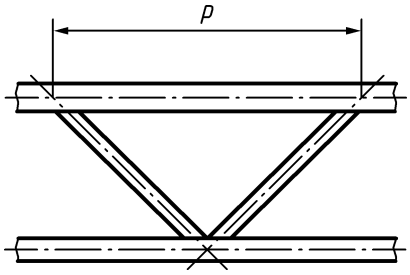
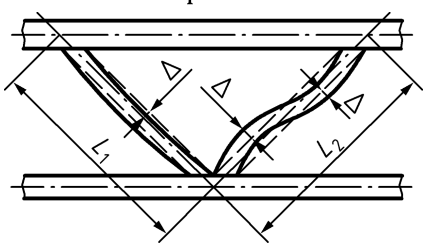
Key:
1 intended joint geometry</td><td colspan="2">Essential tolerances [a]</td></tr>
<tr><td>Class</td><td>Permitted deviation Δ</td></tr>
<tr><td>Class A</td><td>$\Delta = \pm 0{,}14t$
and $\lvert\Delta\rvert \le 2$ mm</td></tr>
<tr><td>Class B</td><td>$\Delta = \pm 0{,}20t$
and $\lvert\Delta\rvert \le 3$ mm</td></tr>
<tr><td>Class C</td><td>$\Delta = \pm 0{,}30t$
and $\lvert\Delta\rvert \le 4$ mm</td></tr>
<tr><td colspan="2">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.</td></tr>
</table>

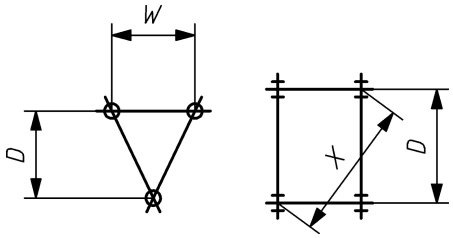
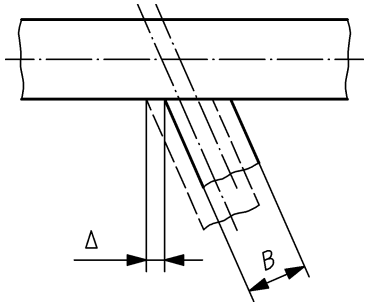
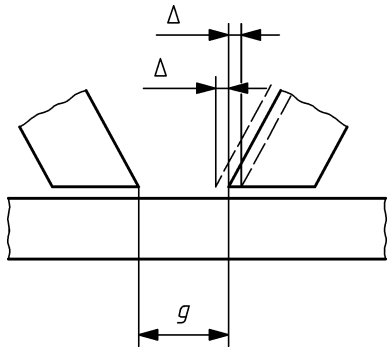
<table>
<tr><th>No</th><th colspan="3">Criteria and details</th></tr>
<tr><td>3</td><td>Dents (Dimples) [b]:
Meridionally:
$L = 4\ (rt)^{0,5}$
Circumferentially (gauge radius = r = the nominal radius of the middle surface of the shell):
$L = 4\ (rt)^{0,5}$
unless it is specified that $L = 2{,}3\ (h^2rt)^{0,25}$ with $L \le r$
where h is the axial length of the shell segment
Additionally, across welds [c]:
$L = 25t$ but $L \le 500$ mm
NOTE At a change of thickness: t = the smaller thickness</td><td> 

Key:
1 inward</td><td> 

Essential tolerances [a]
<table>
<tr><th>Class</th><th>Permitted deviation Δ</th></tr>
<tr><td>Class A</td><td>$\Delta = +\ 0{,}006L$</td></tr>
<tr><td>Class B</td><td>$\Delta = +\ 0{,}010L$</td></tr>
<tr><td>Class C</td><td>$\Delta = +\ 0{,}016L$</td></tr>
</table></td></tr>
<tr><td colspan="4">[a] No functional tolerance specified.
[b] Dimple measurements are made using gauges of length L (straight for meriodinal direction and curved for circumferential direction) with the scope of checking to be given in the execution specification.
[c] Figure 8.4 of EN 1993-1-6: 2007 illustrates measurements across welds.</td></tr>
<tr><td colspan="4">NOTE With reference to the manufacturing tolerance quality classes in EN 1993–1–6, Class A = Excellent, Class B = High and Class C = Normal.</td></tr>
</table>

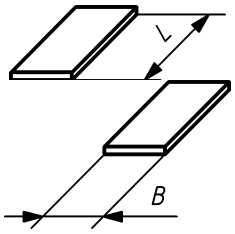
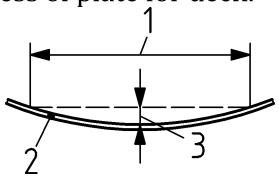
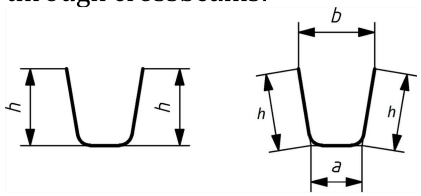
Table B.12 — Manufacturing tolerances - Lattice components

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	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 $\lvert\Delta\rvert \geq 12$ 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:	No requirement	$\Delta = \pm 5$ mm	$\Delta = \pm 3$ mm
		Cumulative deviation Σp of panel point position:	No requirement	$\Delta = \pm 10$ mm	$\Delta = \pm 6$ mm
3	Straightness of bracing components:  	Deviation of bracing lengths L_i (L_1 or L_2) from straightness:	$\Delta = \pm L_i/1000$ but $\lvert\Delta\rvert \geq 4$ mm	$\Delta = \pm L_i/1000$ but $\lvert\Delta\rvert \geq 4$ mm	$\Delta = \pm L_i/1000$ but $\lvert\Delta\rvert \geq 3$ mm

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
4	Cross-sectional dimensions: 	Deviation of distances D, W and X if: $s \leq 300$ mm $300 < s < 1000$ mm $s \geq 1000$ mm where $s = D$, W or X as appropriate.	No requirement	 Δ = ± 3 mm Δ = ± 5 mm Δ = ± 10 mm	 Δ = ± 2 mm Δ = ± 4 mm Δ = ± 6 mm
5	Intersecting joints: 	Eccentricity (relative to specified eccentricity):	No requirement	Δ = ± (B/20 + 5) mm	Δ = ± (B/40 + 3) mm
6	Gap joints: 	Gap g between bracing components: $g \geq (t_1 + t_2)$ where t_1 and t_2 are the wall thicknesses of braces	No requirement	Δ = ± 5 mm	Δ = ± 3 mm

NOTE Notations such as Δ = ± L /500 but |Δ| ≥ 12 mm mean that |Δ| is the *larger* of L /500 and 12 mm.
Notation such as |Δ| = $t_1 + t_2$ but |Δ| ≤ 5 mm means that the *smaller* of the two values is required.

Table B.13 — Manufacturing tolerances - Bridge decks

No	Criterion	Parameter	Functional tolerances Permitted deviation Δ	
			Class 1	Class 2
1	Length *L* depth / width *B* of plate for deck:  	Overall dimensions *L* and *B* after cutting and straightening by rolling inclusive of provisions for shrinkage and after application of the final weld preparation	No requirement	- Δ = 2 mm + Δ = 0 mm
2	Flatness of plate for deck:  Key: 1 gauge length 2000 mm 2 plate 3 deviation Δ	After application of the final weld preparation:	Class S according to EN 10029	Δ = ± 2 mm
3	Formed profile of height *h* and widths *a* and *b* for passing through crossbeams:  	With cope holes: Δ is the deviation of *h* or *a* or *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.	Δ*h* = ± 3 mm Δ*a* = ± 2 mm Δ*b* = ± 3 mm	- Δ = 1 mm + Δ = 2 mm
		Without cope holes: Δ is the deviation of *h* or *a* or *b* 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.	Δ*h* = ± 2 mm Δ*a* = ± 1 mm Δ*b* = ± 2,5 mm	Δ = ± 0,5 mm

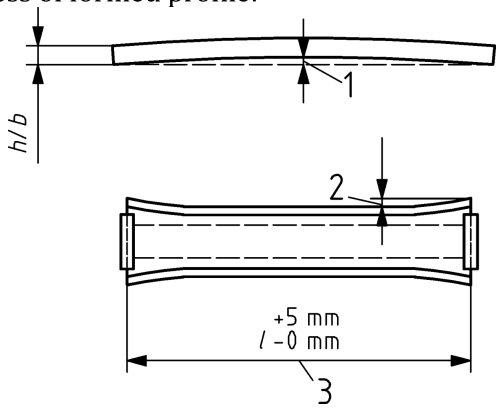
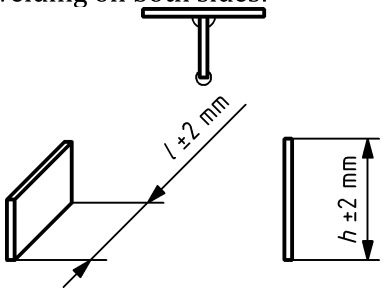
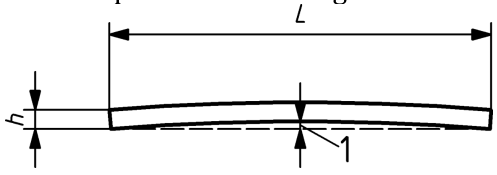
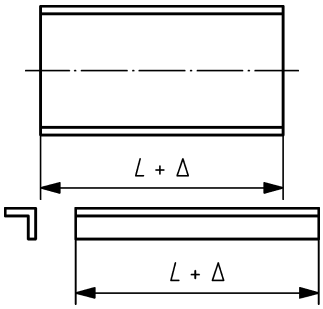
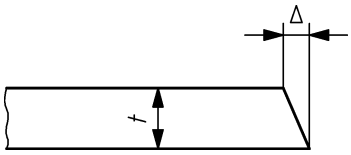
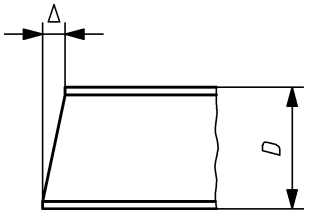
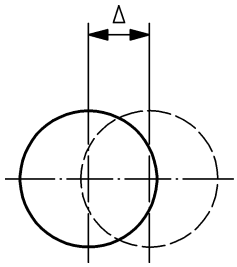
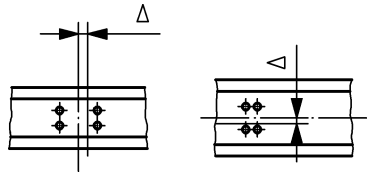
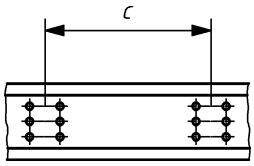
No	Criterion	Parameter	Functional tolerances Permitted deviation Δ	
			Class 1	**Class 2**
4	Straightness of formed profile:  Key: 1 max. gap Δ_1 2 max widening Δ_2 3 for stiffener splices with splice plates Δ_3 radius $r = r \pm \Delta_r$ rotation Δ_φ measured on a plane surface over 4 m length parallelism Δ_p		$\Delta_1 = \pm L/500$ $\Delta_2 = 5$ mm $5 \text{ mm} \geq \Delta_3 \geq 0$ $\Delta_r = \pm 0{,}20\ r$ $\Delta_\varphi = \pm 1°$ $\Delta_p = \pm 2$ mm	$\Delta_1 = \pm L/1000$ $\Delta_2 = 1$ mm $5 \text{ mm} \geq \Delta_3 \geq 0$ $\Delta_r = \pm 2$ mm $\Delta_\varphi = \pm 1°$ $\Delta_p = \pm 2$ mm
5	Length / width of flat profile for welding on both sides:  	Overall dimensions *l, h*	$\Delta = \pm 2$ mm	$\Delta = \pm 2$ mm
6	Straightness of flat profile for welding on both sides:  Key: 1 max. gap Δ_1 Length Δ_L		$\Delta_1 = \pm L/1000$ $5 \text{ mm} \geq \Delta_L \geq 0$	$\Delta_1 = \pm L/1000$ $5 \text{ mm} \geq \Delta_L \geq 0$

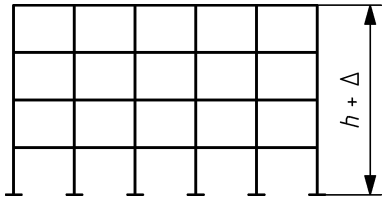
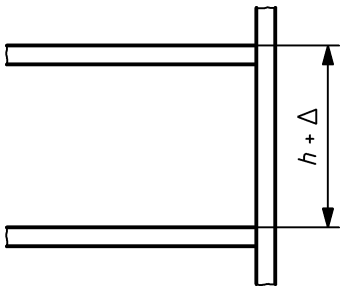
Table B.14 — Manufacturing tolerances - Towers and masts

No	Criterion	Parameter	Functional tolerance[a] 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 = ± 2 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 = ± 1 mm	Δ = ± 0,5 mm
4	Squareness of cut edges: 	Deviation Δ of a cut edge from 90°:	Δ = ± 0,05t	Δ = ± 0,05t
5	Squareness of ends: 	Squareness to longitudinal axis: - ends intended for full contact bearing: - ends not intended for full contact bearing:	Δ = ± D /1000 Δ = ± D /300	Δ = ± D /1000 Δ = ± D /300
6	Surfaces intended for full contact in bearing:	Flatness:	1 in 1500	1 in 1500
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

No	Criterion	Parameter	Functional tolerance[a] Permitted deviation Δ	
			Class 1	Class 2
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 = ± 1,5 mm	Δ = ± 0,5 mm
a No essential tolerance specified.				

B.3 Erection tolerances

Table B.15 — Erection tolerances - Buildings

No	Criterion	Parameter	Functional tolerances [a] 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	 Δ = ± 20 mm Δ = ± 0,5 (h+20) mm Δ = ± 0,2 (h+200) m m [h in metres]	 Δ = ± 10 mm Δ = ± 0,25(h+20) mm Δ = ± 0,1 (h+200) mm [h in metres]
2	Storey height: 	Height relative to the adjacent levels:	Δ = ± 10 mm	Δ = ± 5 mm

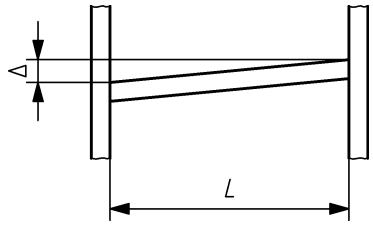
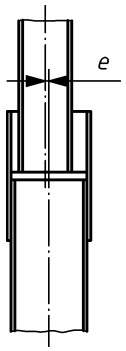
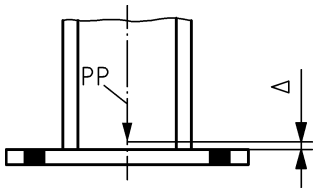
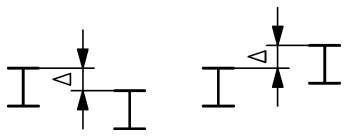
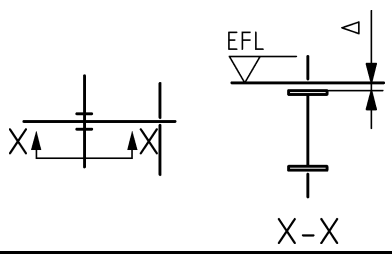
No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ	
			Class 1	**Class 2**
3	Slope: 	Height relative to the other end of a beam:	Δ = ± *L* /500 but |Δ| ≤ 10 mm	Δ = ± *L* /1000 but |Δ| ≤ 5 mm
4	Column slice 	Non-intended eccentricity *e* about either axis:	5 mm	3 mm
5	Column base: 	Level of bottom of column shaft, relative to specified level of its position point (PP):	Δ = ± 5 mm	Δ = ± 5 mm
6	Relative levels: 	Levels of adjacent beams, measured at corresponding ends:	Δ = ± 10 mm	Δ = ± 5 mm
7	Connection levels: 	Level of the beam at a beam-to-column connection, measured relative to the established floor level (EFL):	Δ = ± 10 mm	Δ = ± 5 mm
a	No essential tolerance specified			

Table B.16 — Erection tolerances - Beams in buildings

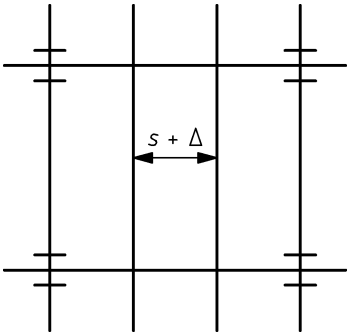
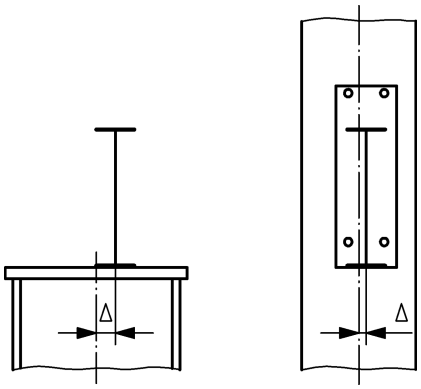
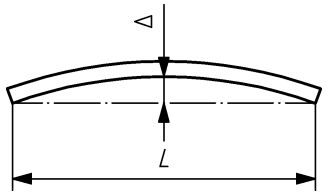
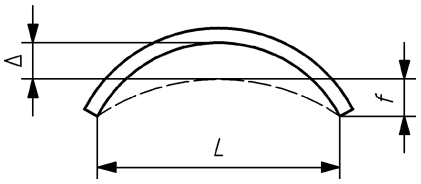
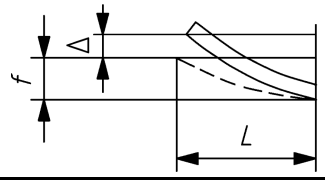
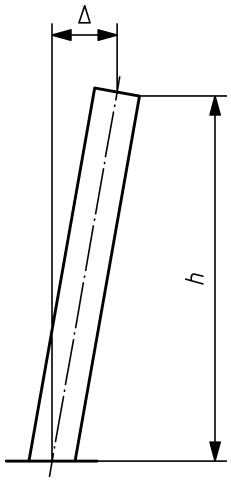
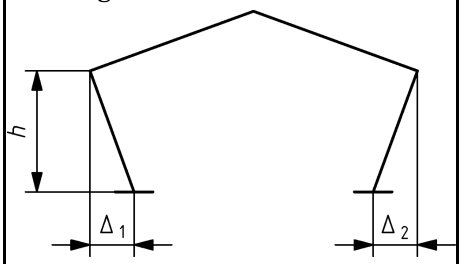
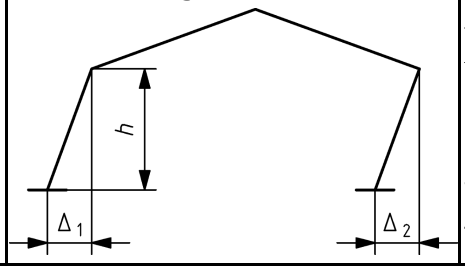
No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ	
			Class 1	Class 2
1	Spacing between beam centrelines: 	Deviation Δ from intended distance (*s*) between adjacent erected beams, measured at each end:	Δ = ± 10 mm	Δ = ± 5 mm
2	Location at columns: 	Deviation Δ from intended location of a beam-to-column connection, measured relative to the column:	Δ = ± 5 mm	Δ = ± 3 mm
3	Straightness in plan: 	Deviation Δ from straightness of an erected beam or cantilever of length *L:*	Δ = ± *L* /500	Δ = ± *L* /1000
4	Camber: 	Deviation Δ at mid span from intended camber *f* of an erected beam or lattice component of length *L*:	Δ = ± *L* /300	Δ = ± *L* /500
5	Pre-set of cantilever: 	Deviation Δ from intended pre-set at end of an erected cantilever of length *L*:	Δ = ± *L* /200	Δ = ± *L* /300
a No essential tolerance specified				

Table B.17 — Erection tolerances - Columns of single storey buildings

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
1	Inclination of columns of single-storey buildings: 	Overall inclination in storey height *h*:	Δ = ± *h* /300	Δ = ± *h* /300	Δ = ± *h* /500
2	Inclination of individual columns in single storey portal frame buildings: 	Inclination Δ of each column: Δ = Δ_1 or Δ_2	No requirement	Δ = ± *h* /150	Δ = ± *h* /300
3	Inclination of single storey portal frame buildings: 	Average inclination of all the columns in the same frame: [For two columns the average is: Δ = (Δ_1 + Δ_2)/2]	Δ = ± *h* /500	Δ = ± *h* /500	Δ = ± *h* /500

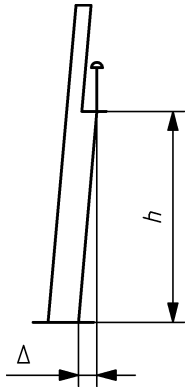
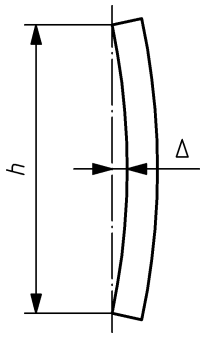
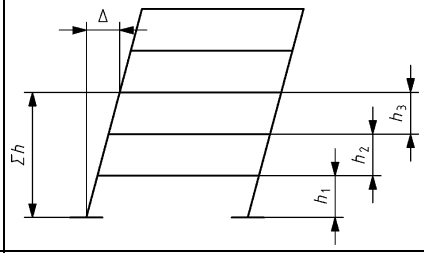
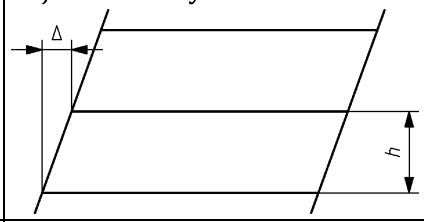
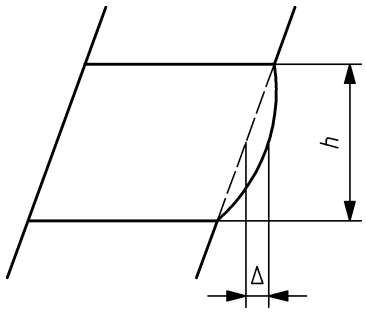
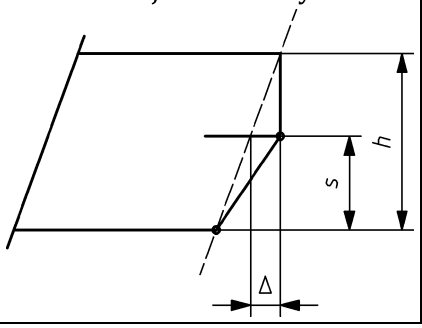
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
4	Inclination of any column that supports a crane gantry: 	Inclination from floor level to bearing of crane beam:	Δ = ± *h* /1000	Δ = ± 25 mm	Δ = ± 15 mm
5	Straightness of a single storey column: 	Location of the column in plan, relative to a straight line between position points at top and bottom:	Δ = ± *h* /1000	No requirement	No requirement

Table B.18 — Erection tolerances - Multi-storey buildings

No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ	
			Class 1 and 2	Class 1	Class 2
1	Location at the storey level *n* levels above the base, relative to that at the base: 	Location of the column in plan, relative to a vertical line through its centre at base level:	$\Delta = \pm \Sigma h / (300\sqrt{n})$	$\Delta = \pm \Sigma h / (300\sqrt{n})$	$\Delta = \pm \Sigma h / (500\sqrt{n})$
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:	$\Delta = \pm h/300$	$\Delta = \pm h/300$	$\Delta = \pm h/500$
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:	$\Delta = \pm h/1000$	$\Delta = \pm h/1000$	$\Delta = \pm h/1000$
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:	$\Delta = \pm s/1000$ with $s \le h/2$	$\Delta = \pm s/1000$ with $s \le h/2$	$\Delta = \pm s/1000$ with $s \le h/2$

NOTE Table B.18 “Multi-storey buildings” applies to columns that are continuous over more than one storey. Table B.17 applies to storey-height columns in multi-storey buildings.

Table B.19 — Erection tolerances - Full contact end bearing

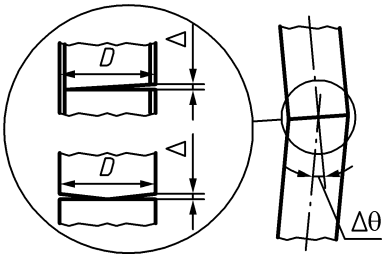
No	Criterion	Parameter	Essential tolerances Permitted deviation Δ	Functional tolerances Permitted deviation Δ
			Class 1 and 2	Class 1 and 2
1	Local angular misalignment Δθ occurring at the same time as gap Δ at point "X": 		$\Delta\theta$ = ± 1/500 and Δ = 0,5 mm over at least two thirds of the area, and Δ = 1,0 mm maximum locally	No requirement

Table B.20 — Erection tolerances - Positions of columns

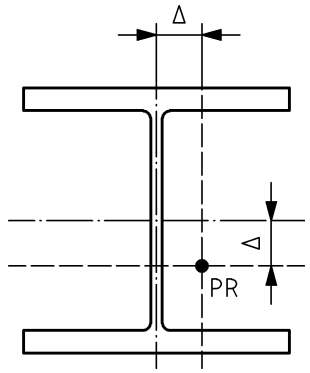
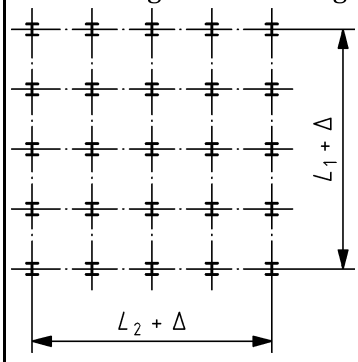
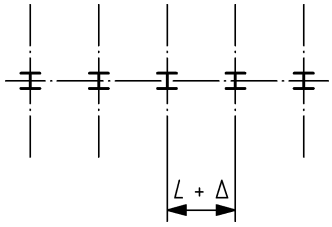
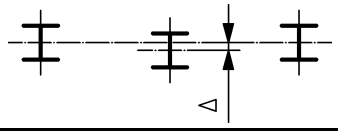
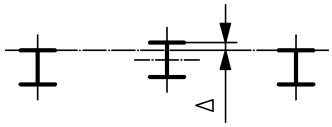
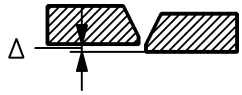
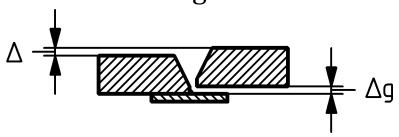
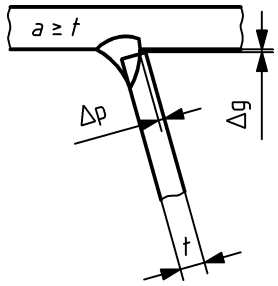
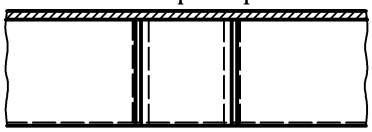
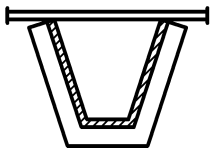
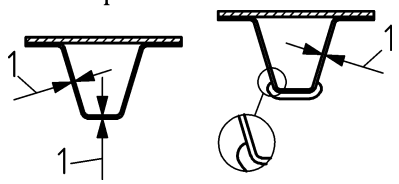
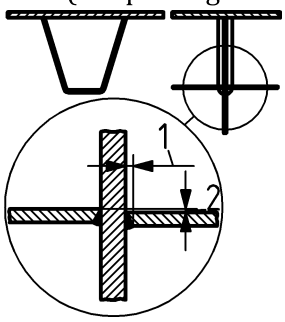
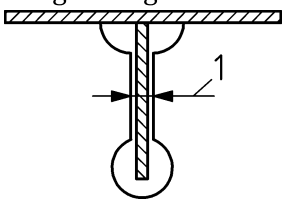
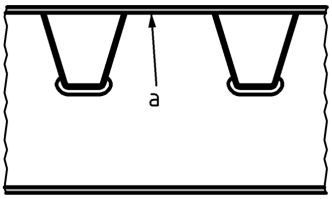
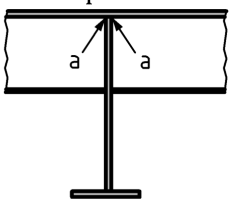
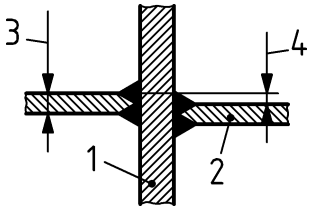
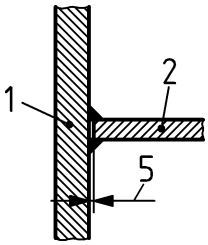
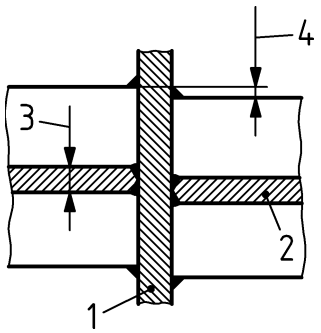
No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ	
			Class 1	Class 2
1	Location: 	Location in plan of the centre of the column at the level of its base, relative to the position point of reference (PR):	Δ = ± 10 mm	Δ = ± 5 mm
2	Overall length of a building: 	Distance between end 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) m m [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
a No essential tolerance specified				

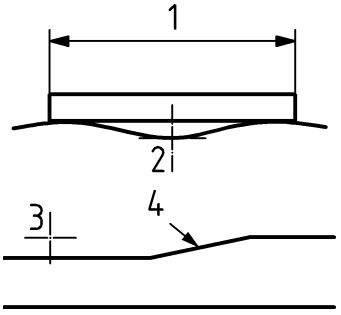
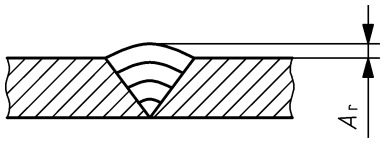
Table B.21 — Erection tolerances - Bridge decks

No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ
1	Misalignment of splices of deck plate without backing strip or splice of lower flange or web of crossbeam: 	Misalignment Δ before welding:	Δ = 2 mm
2	Misalignment and fit up of splices of deck plate with backing strip left in place after welding: 	Misalignment Δ after tacking and before welding: Gaps Δ_g between plate and backing strip after welding (weld not shown):	Δ = 2 mm Δ_g = 1 mm
3	Welding of stiffener-deck plate connection with weld with nominal throat, *a*: 	Lack of root penetration Δ_p: Fit up gap Δ_g before and after welding:	Δ = 2 mm Δ = 2 mm
4	Misalignment of stiffener-stiffener connection with splice plates:  	Misalignment Δ between stiffener and splice plate before welding:	Δ = ± 2 mm
5	Misalignment at stiffener to stiffener connection with splice plates: 	Misalignment Δ before welding:	Δ = 2 mm

No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ
6	Gaps around stiffener-to-crossbeam connection with stiffeners passing through the crossbeam with or without cope holes  Key: 1 max. gap Δ	Gaps before welding:	Δ = 3 mm
7	Misalignment of and gaps around stiffener-to-crossbeam connection with stiffeners fitted between crossbeams (not passing through)  Key: 1 max. gap Δ_1 2 misalignment Δ_2 before welding	Gaps before welding:	Δ_1 = 2 mm
		Misalignment before welding:	Δ_2 = ± 2 mm
8	Stiffener-crossbeam connection with flats passing through  Key: 1 max. gap Δ around flat	Gaps before welding:	Δ = 1 mm

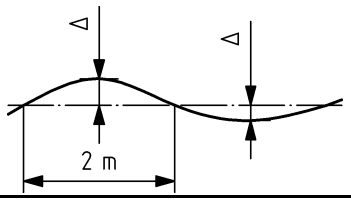
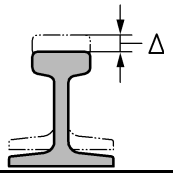
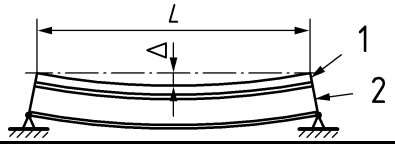
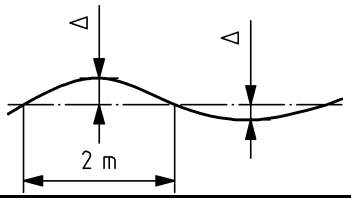
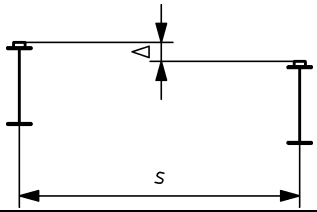
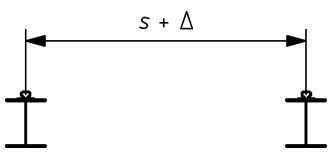
No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ
9	Gaps in connection of web of crossbeam to deck plate (with or without cope holes)  Gaps before welding:  Key: *a* connection of web of crossbeam to deck plate		Δ = 1 mm
10	Misalignment of and gaps around connection of webs of crossbeams to web of main girder for continuous crossbeams  for non-continuous crossbeams  Key: 1 web of main girder 2 web of crossbeam 3 thickness of crossbeam web, $t_{w,crossb}$ 4 misalignment of webs Δ_w 5 gap Δ_g	Gaps before welding: Misalignment before welding:	Δ_g = 2 mm Δ_w = ± 0,5 $t_{w,crossb}$

No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ
11	Misalignment of connection of crossbeam flanges to web of main girder and weld radius  Key: 1 web of main girder 2 web of crossbeam 3 thickness of crossbeam web, $t_{w,crossb}$ 4 misalignment of flanges Δ_f	Misalignment before welding: Weld radius:	$\Delta = \pm 0,5\ t_{w,crossb}$ The radius, r, of the weld between the flange and the crossbeam web shall be the greater of 8 mm or 0,5 times the thickness of the main girder web, $t_{w,maingirder}$

No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ
12	Fit-up of orthotropic decks of plate thickness, *t*, after erection:  Key: 1 GL gauge length *2* P_r deviation *3* V_e step *4* D_r slope	Step difference V_e, at junction: $t \le 10$ mm: 10 mm < $t \le 70$ mm $t > 70$ mm:	 2 mm 5 mm 8 mm
		Slope, D_r, at junction: $t \le 10$ mm: 10 mm < $t \le 70$ mm: $t > 70$ mm:	 1/12,5 1/11 1/10
		Flatness, P_r, over gauge length, *GL*, in all directions: $t \le 10$ mm: $t > 70$ mm: General case: Longitudinally: Values for P_r may be interpolated for 10 mm < $t \le 70$ mm.	 3 mm for *GL* of 1 m 4 mm for *GL* of 3 m 5 mm for *GL* of 5 m 5 mm for *GL* of 3 m 18 mm for *GL* of 3 m
13	Weld protrusion for orthotropic deck:  	Protrusion A_r of weld above surrounding surface:	– A_r = 0 mm + A_r = 2 mm

[a] No essential tolerance specified

Table B.22 — Erection tolerances - Crane runways

No	Criterion	Parameter	Functional tolerances [a] 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 /1000 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 with span s: 	Deviation of level: for s ≤ 10 m for s > 10 m	Δ = ± 20 mm Δ = ± s /500	Δ = ± 10 mm Δ = ± s /1000
7	Spacing over span 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 [s in metres]	Δ = ± 5 mm Δ = ± (5+[s-16]/4) mm [s in metres]

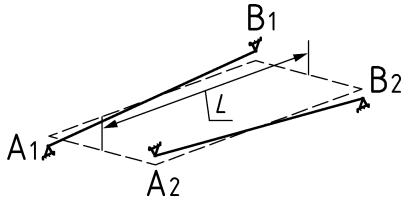
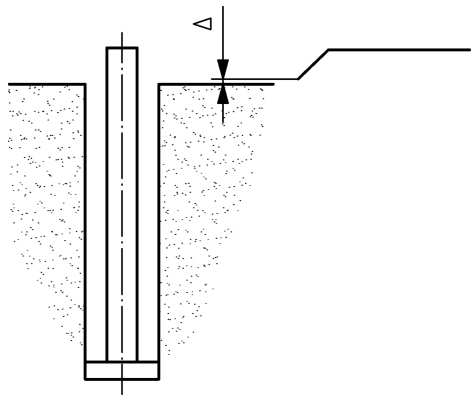
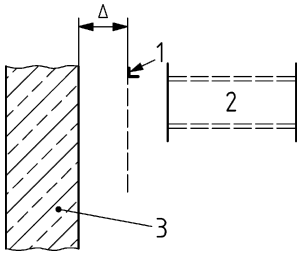
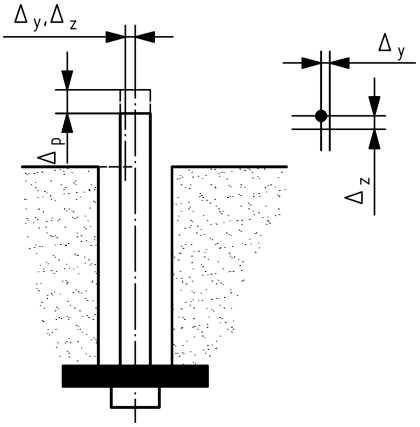
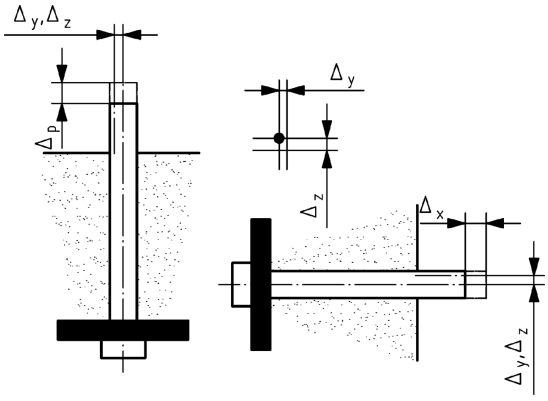
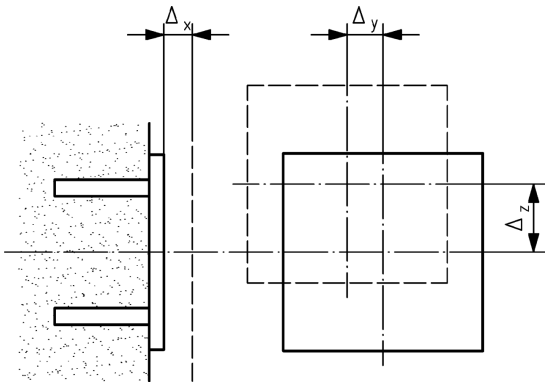
No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ	
			Class 1	Class 2
8	Structural end stops:	Relative location of the stops at the same end, measured in the direction of travel on the runway	$\Delta = \pm s/1000$ but $\lvert\Delta\rvert \leq 10$ mm	$\Delta = \pm s/1000$ but $\lvert\Delta\rvert \leq 10$ mm
9	Inclination of opposite rails:  L distance of adjacent supports	Offset: $\Delta = \lvert N_1 - N_2 \rvert$ where: N_1 inclination A_1 B_1 N_2 inclination A_2 B_2	$\Delta = L/500$	$\Delta = L/1000$
[a] No essential tolerance specified				

Table B.23 — Erection tolerances - Concrete foundations and supports

No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ
1	Foundation level: 	Deviation from specified level:	- Δ = 15 mm (below) + Δ = 5 mm (above)
2	Vertical wall:  Key: 1 specified position 2 steel component 3 supporting wall	Deviation from specified position at support point for steel component:	Δ = ± 25 mm

No	Criterion	Parameter	Functional tolerances [a] Permitted deviation Δ
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 - Δ_P = 5 mm (low) + Δ_P = 25 mm (high)
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 - Δ_p = 5 mm (low) + Δ_p = 45 mm (high) - Δ_x = 5 mm (in) + Δ_x = 45 mm (out)
5	Steel anchor plate embedded in concrete:  	Deviations Δ_x, Δ_y, Δ_z from the specified location and level:	Δ_x, Δ_y, Δ_z = ± 10 mm

[a] No essential tolerance specified

Table B.24 — Erection tolerances - Towers and masts

No	Criterion	Parameter	Essential tolerances [a] Permitted deviation Δ
1	Straightness of legs and chord components:	Straightness of portion (L) between joint locations:	$L/1000$
2	Main dimensions of mast cross section and bracing:	Panel < 1000 mm: Panel ≥ 1000 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 [b]:	Δ = ± 0,05 % but |Δ| ≥ 5 mm
6	Verticality of a tower:		Δ = ± 0,20 % but |Δ| ≥ 5 mm
7	Twist Δ over full height of structure [see NOTE 1]:	Structure < 150 m: Structure ≥ 150 m:	Δ = ± 2,0° Δ = ± 1,5°
8	Twist Δ between adjacent levels of the structure [see NOTE 1]:	Structure < 150 m: Structure ≥ 150 m:	Δ = ± 0,10° per 3 metres Δ = ± 0,05° per 3 metres

[a] No functional tolerance specified

[b] The permitted deviations for verticality are default values that may be superseded by other less onerous values given in the execution specification, provided these are in accordance with verticality assumptions in the design of the mast or tower.

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 |Δ| is the *larger* of 0,10 % and 5 mm.

Table B.25 — Erection tolerances - Beams subject to bending and components subject to compression

No	Criterion	Parameter	Essential tolerances [a] Permitted deviation Δ
1	Straightness of beams subject to bending and components subject to compression if unrestrained	Deviation Δ from straightness:	Δ = ± $L/750$

[a] No functional tolerance specified

Annex C
(informative)

Check-list for the content of a quality plan

C.1 General

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. It is developed with reference to the general guidelines in ISO 10005.

C.2 Content

C.2.1 Management

— Definition of the particular steel structure and its location with relation to the project;

— Project management organization 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 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 ensured 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:

1) certificates for constituent products including consumables;

2) weld procedure specifications and qualification records;

3) method statements including those for erection and preloading fasteners;

4) design calculations for temporary works necessitated by the erection methods;

5) 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:

1) constituent products traced to completed components;

2) inspection and test reports and action taken to deal with nonconformities, concerning:

i) preparation of joint faces prior to welding;

ii) welding and completed weldments;

iii) geometrical tolerances of manufactured components;

iv) surface preparation and treatment;

v) calibration of equipment including those used for control of preloading of fasteners;

3) pre-erection survey results leading to acceptance that the site is suitable for erection to commence;

4) delivery schedules for components delivered to site identified to location with the completed structure;

5) dimensional surveys of the structure and action taken to deal with nonconformities;

6) 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 ten years, or longer if required by the project.

C.2.4 Inspection and testing procedures

a) 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:

   1) the scope of inspection;

   2) acceptance criteria;

   3) actions for dealing with nonconformities and corrections;

   4) release/rejection procedures.

b) 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;

c) Identification of hold points associated with second or third party witnessing, approval or acceptance of test or inspection results.

Annex D
(informative)

Procedure for checking capability of automated thermal cutting processes

D.1 General

This Annex provides guidance on procedures for testing and assessment of automated thermal cutting processes in accordance with EN 1090-2 and EN ISO 9013.

This procedure may be applied to all automated thermal cutting processes including laser and plasma cutting.

NOTE Some different or additional parameters may be needed for control of laser and plasma cutting.

The basis for the procedure for checking the capability of automated thermal cutting processes follows the general rules for specification and qualification of welding procedures in EN ISO 15607.

The procedure is based on preparing a preliminary cutting procedure specification (pCPS) and verifying the quality of the cut surfaces produced using this pCPS in order to finalise a cutting procedure qualification record (CPQR). This CPQR is then used as the basis for control of cutting operations in production using cutting procedure specifications (CPSs).

Table D.3 gives an example of a CPQR. Table D.4 gives an example of a pCPS and CPS.

The CPQR includes a range of qualification within which it may be used. Ranges are given for the following variables:

a) Group of material;

b) Material thickness;

c) Pressures of gases;

d) Cutting speed and height;

e) Preheat temperature.

Unless otherwise specified, the verification of the quality of the cut surfaces may be done under the authority of the Responsible Welding Coordinator acting as test investigator and assessor. A test report shall be produced summarizing the results of tests upon which the CPQR is based.

NOTE The terms and definitions used in this Annex are explained in EN ISO 9013.

D.2 Description of the procedure

D.2.1 General

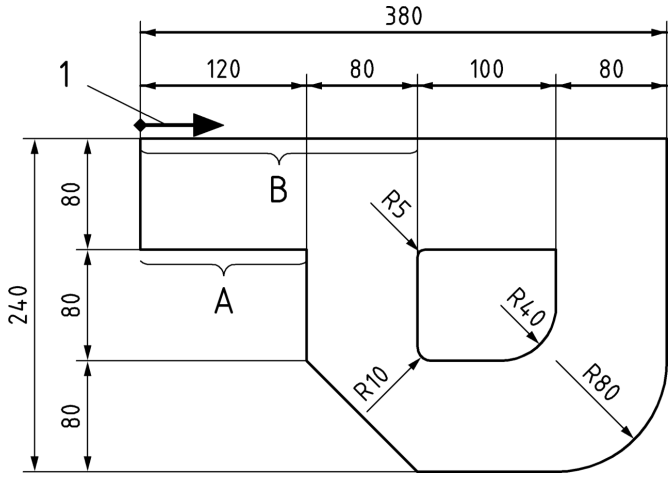
Cutting of the test pieces shall be conducted according to a preliminary cutting procedure specification (pCPS) where all of the parameters and influences relevant to the process are stated.

In accordance with EN 1090-2, the perpendicularity and angularity tolerance, the average surface roughness as well as the hardness of the edges of cut may be determined. If the cutting process is to be used only for perpendicular cuts, then the angularity tolerance does not need to be determined. In this case, the use of a test piece as shown in Figure D.1 is recommended. If the cutting process is to be used for bevel cuts, then the angularity tolerance needs to be determined.

NOTE If bevel cuts are used to make welding preparations, the angularity tolerance of a bevel cut may not be critical if the surface is subsequently dressed.

The test piece(s) shall have a straight cut, a sharp edged corner as well as a curve-shaped bend. The edges of cut in the areas of the curve-shaped bend as well as of the sharp-edged corner shall have a comparable or higher quality as in the area of the straight cut in relation to the perpendicularity and angularity tolerance respectively as well as to surface roughness. The above parameters shall be determined in the areas of the straight cut with the hardness test having to be particularly conducted in the areas with the highest cutting and cooling speed, respectively.

Dimensions in mm



Key

1 start of procedure and direction of cutting

NOTE Measurements are taken on the straight area B over at least a 200 mm length and hardness are measured in areas A and B on each sample and checked against the required quality class. The sharp corner and curved samples are inspected by visual test to establish that they produce edges of equivalent standard to the straight cuts.

Figure D.1 — Recommended shape of test piece and location of measurements (dimensions in mm)

D.2.2 Average surface roughness R_{Z5}

The average surface roughness R_{Z5} shall be determined in accordance with EN ISO 9013.

At a location representative of the straight flame cut, the surface roughness shall be measured transverse to the groove path along a length of a maximum of 40 mm (see Figure D.2).

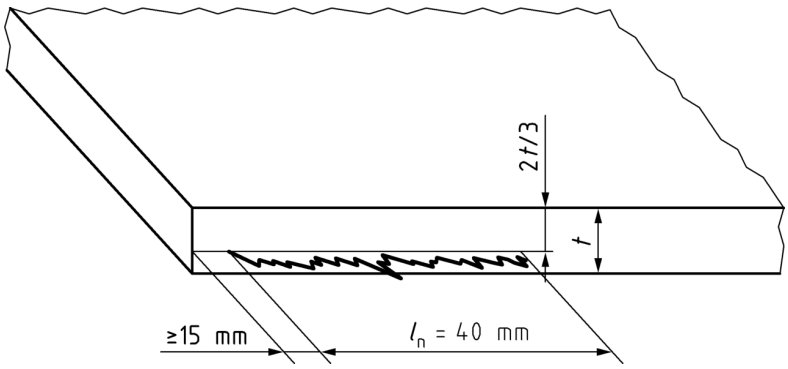


Figure D.2 — Location of surface roughness measure for straight flame cut

The arithmetic average of the single profile elements of five adjacent single measurements (Z_{t1} to Z_{t5} as shown in Figure D.3) shall be used to calculate the average surface roughness R_{Z5}.

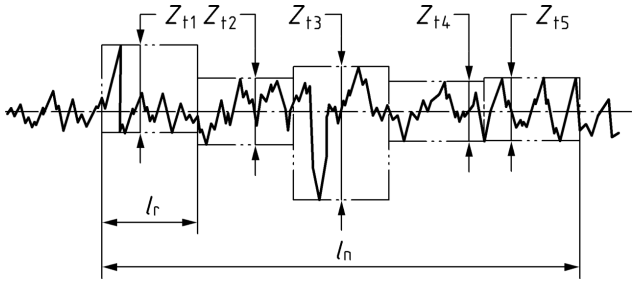


Figure D.3 — Determination of the average surface roughness R_{Z5}

In order to determine the average surface roughness R_{Z5}, a surface roughness tester suitable for high roughnesses shall be used. A sufficient and stable contact surface of the device shall be provided.

For plate thicknesses (t) < 6 mm, additional strips with a smooth surface shall be attached flush with the cut edge to the sides of the plate surfaces of the test piece to be tested using a clamp, in order to ensure sufficient contact.

The highest value of surface roughness R_{Z5} with the respective distance of the upper edge of the plate shall be determined and recorded.

D.2.3 Perpendicularity and angularity tolerance

The perpendicularity and angularity tolerance (u) shall be determined in accordance with EN ISO 9013 with respect to both vertical and bevel cuts. A measuring microscope may also be used in a transverse section. When preparing the transverse section an edge of the cut free of burrs shall be provided.

The perpendicularity or angularity tolerance (u) shall be determined at a representative spot (highest measured value to be expected) of the straight flame cut.

For a better contrast during the measurement, the test piece may be etched using a suitable etching agent. Depending on the plate thickness, several exposures may be completed to form one figure and measured. The reduction of thickness of the cut (Δa) shall be recorded, which limits the area to be measured.

D.2.4 Hardness test

The hardness test on the flame cut edge shall be performed in accordance with EN ISO 6507-1.

The test pieces for the measurement of the hardness shall have plane, parallel contact surfaces. Grinding of the flame cut edges shall be conducted using grain size 600. The flame cut surface shall be ground so

that some indentations of the flame cut surface are still visible. Hardness measurements shall be taken in the areas near the upper and lower edges as well as the centre of the plate thickness (see Figure D.4).

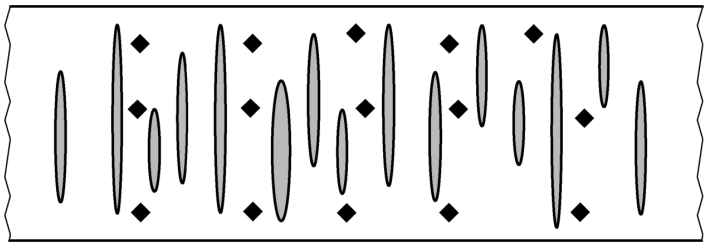


Figure D.4 — Measurement locations on ground flame cut surface

Depending on the plate thickness, either 5 or 15 measurements of the hardness distributed across the cross-section shall be conducted (see Table D.1). During the hardness test near the plate surfaces the minimum distance in accordance with EN ISO 6507-1 as well as the melting of the surfaces shall be observed.

Table D.1 — Number and area of hardness measurements

Plate thickness t [mm]	Hardness measurements
$t \leq 5$	5, at centre of the plate thickness
$t > 5$	5, near upper side of the plate 5, near lower side of the plate 5, at centre of the plate thickness

D.3 Range of qualification

D.3.1 Material groups

Due to the hardening behaviour of the different materials, Table D.2 shall be used to determine the range of validity.

Table D.2 — Material groups

Test piece **Material group from** CEN ISO/TR 15608	**Range** **Material groups according to** CEN ISO/TR 15608
1	1[a], 2[b]
1.4	1[b], 2[b]
2	1.1, 2[b]
3	1[a], 2[b], 3[b]
[a] Except for 1.4 and valid for steel with the same or lower determined minimum yield strength [b] Valid for steel with the same or lower determined minimum yield strength	

Independent of Table D.2, the preheating temperature may need adjustment for materials within the range but having a higher carbon equivalent than the test piece, to ensure that the increase in hardness of the cut surface is not unacceptable.

D.3.2 Material thickness

Testing of the thinnest and the thickest test piece shall qualify all material thicknesses within this scope of thickness.

D.3.3 Pressures of gases

The qualification is valid within the following ranges:

— heating oxygen pressure: +0 % / –20 %;

— fuel gas pressure: +/– 5 %;

— cutting oxygen pressure: +0 % / –15 %.

D.3.4 Cutting speed and height

The qualification is valid within the following ranges:

— cutting speed: +10 % / –0 %;

— cutting height between cutting head tip and plate: +/–10 %.

D.3.5 Preheat temperature

The qualification is valid within the following range:

— preheat temperature: +/–10 %.

D.4 Test report

The test report shall comprise the following information:

— reference to EN 1090-2 and EN ISO 9013;

— number of the cutting specification pCPS;

— marking of the test piece;

— material;

— plate thickness;

— type of test piece;

— sketch with testing positions on the flame cut edge (if necessary);

— measuring instruments;

— tests conducted and assessment criteria;

— test results;

— evaluation of the test results.

Table D.3 — Example of cutting procedure qualification record

Cutting procedure qualification record							
(p)CPS-No.:		CPQR-No.:					
Manufacturer of the thermal cut sample:							
Address of manufacturer:		Appendices:	1	Cutting-parameters		page	
Standard:			2	Material test report		page	
Date of manufacture:			3	Inspection certificate		page	
Manufacturer:							

Specifications of the cutting procedure qualification record	
Cutting process:	
Manufacturer of the cutting machine:	
Type of cut:	
Designation of the cutting torch:	
Designation of the cutting nozzle:	
Manufacturer of the cutting torch/nozzle:	
Standard:	
Material group:	
Thickness of the material (mm):	
Type of fuel gas:	
Heating oxygen pressure:*	
Fuel gas pressure:*	
Cutting oxygen pressure:*	
Adjustment of the heating flame:	
Cutting speed:	
Cutting height:	
Preheat temperature:	
Thermal follow-up treatment:	
Type of pre-/post-heating torch:	
Designation of the heating torch:	
Manufacturer of the heating torch:	
Type of fuel gas:	
Oxygen/ compressed air pressure:	
Fuel gas pressure:	
* Pressure measured at the inlet of the torch	
This record confirms that the manufacturing of the thermal cut sample was satisfactorily prepared, produced and tested according to the requirements of 6.4.3 and 6.4.4 of EN 1090–2: EXC2 / EXC3 / EXC4 (*delete as appropriate*)	
Place and date of issue:	
Manufacturer’s representative: Name, date and signature:	
Examiner or examining body: Name, date and signature (if other than manufacturer’s RWC):	

Table D.4 — Example of a preliminary cutting procedure specification

Cutting procedure specification	
Cutting process:	
Manufacturer of the cutting machine:	
Type of cut:	
Designation of the cutting torch:	
Designation of the cutting nozzle:	
Manufacturer of the cutting torch/nozzle:	
Standard:	
Material group:	
Thickness of the material (mm):	
Type of fuel gas:	
Heating oxygen pressure:*	
Fuel gas pressure:*	
Cutting oxygen pressure:*	
Adjustment of the heating flame:	
Cutting speed:	
Cutting height:	
Preheat temperature:	
Angle of cut (if bevel not perpendicular):	
Thermal follow-up treatment:	
Type of pre-/post-heating torch:	
Designation of the heating torch:	
Manufacturer of the heating torch:	
Type of fuel gas:	
Oxygen/ compressed air pressure:	
Fuel gas pressure:	
* Pressure measured at the inlet of the torch	

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) unless the hollow sections to be joined are the same size, the 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.

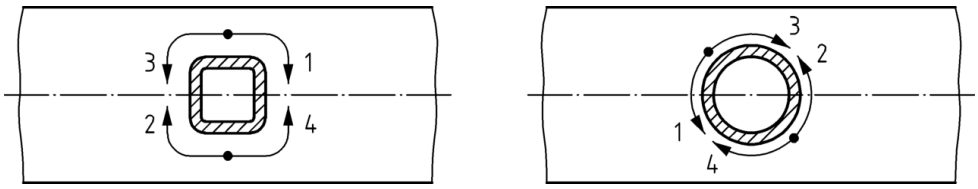


Figure E.1 — Start and stop positions and welding sequence

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

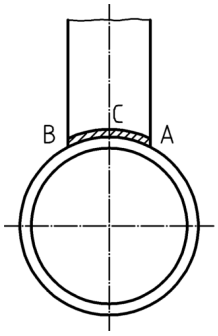
In accordance with 7.5.4, assembly of hollow section components to be welded shall be in accordance with the following requirements:

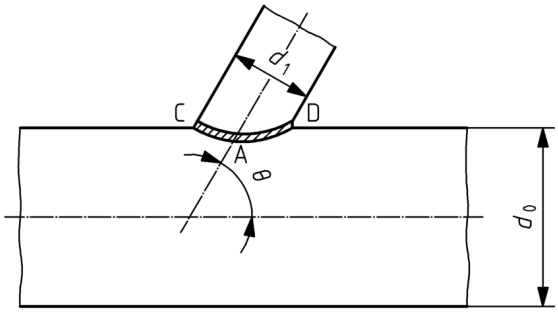
a) assembly using non-overlapping welding of the separate components is preferred (Case A in Figure E.7);

b) assembly of overlapping components should be avoided; if necessary Case B in Figure E.7 is acceptable;

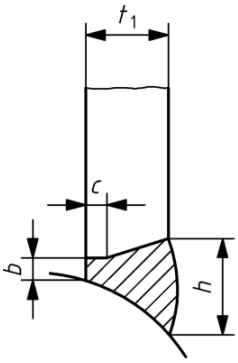
c) if components overlap (as Case B), the welding details shall specified which components are to be cut to fit around other components;

d) the hidden toe area (as Case B) shall be welded unless otherwise specified.





Detail at A, B:

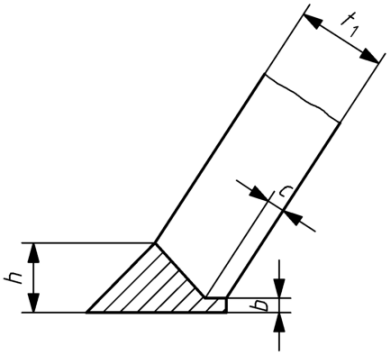


where $d_1 < d_0$

b = 2 mm to 4 mm

c = 1 mm to 2 mm

Detail at C:

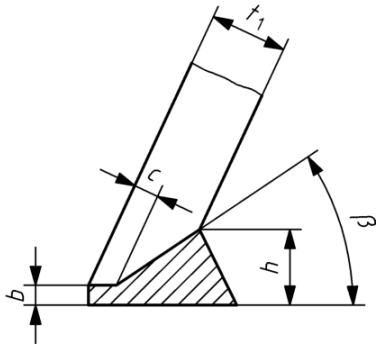


θ = 60° to 90°

b = 2 mm to 4 mm

c = 1 mm to 2 mm

Detail at D:

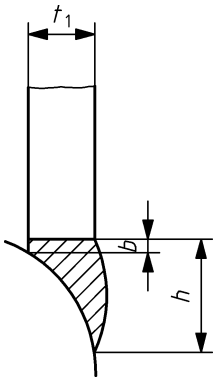


θ = 60° to 90°

b = 2 mm to 4 mm

c = 1 mm to 2 mm

For θ < 60°, a fillet weld detail (as Figure E.3) should be used at D in the heel area.

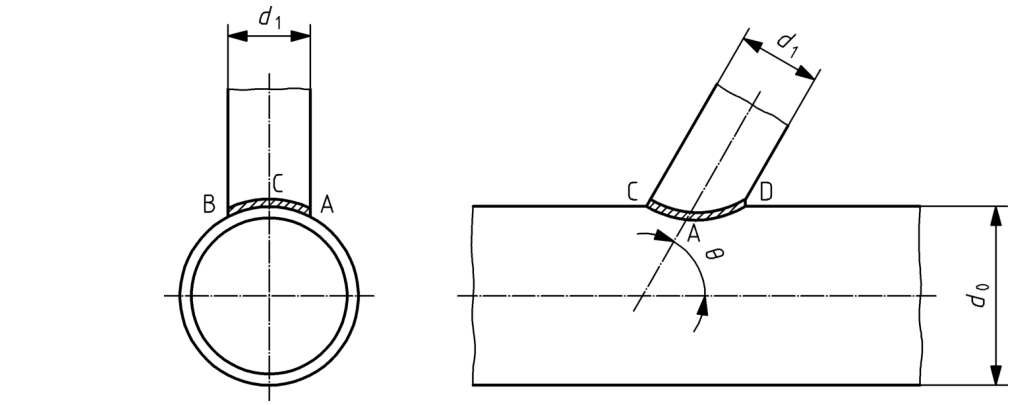


where $d_1 = d_0$

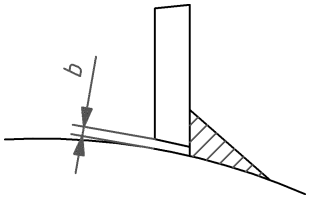
b = max. 2 mm

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

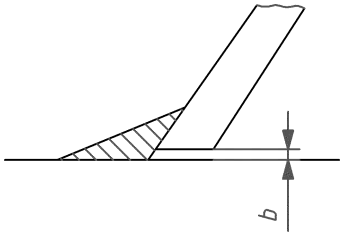


Detail at A, B:



b = max. 2 mm

Detail at C:

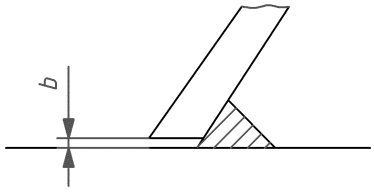


$60° \leq \theta < 90°$

b = max. 2 mm

For θ < 60°, a butt weld detail (as Figure E.2) should be used at C in the toe area.

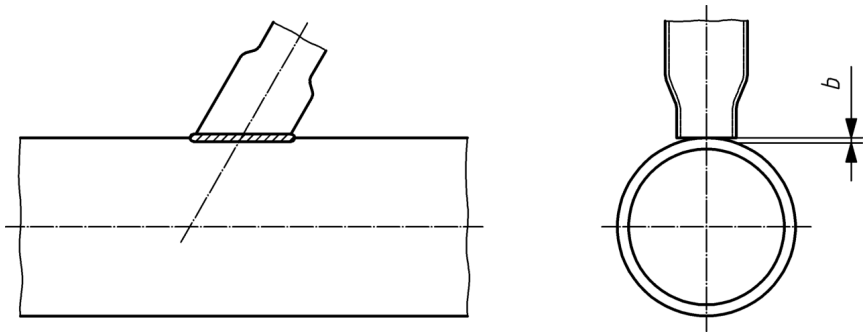
Detail at D:



$30° \leq \theta < 90°$

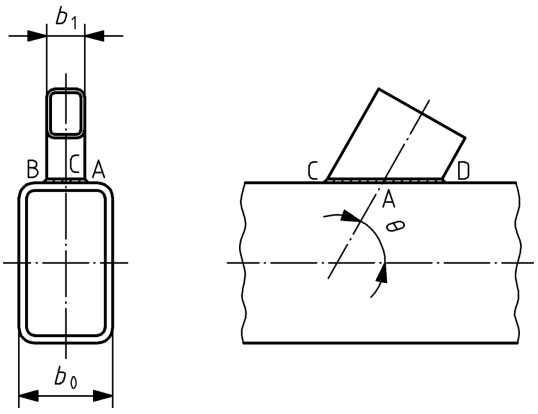
b = max. 2 mm

For the smaller angles, full penetration is not required provided there is adequate throat thickness.

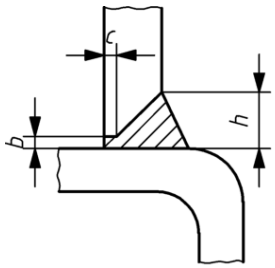


NOTE Application of EN ISO 9692-1 case 3.1.1 to circular hollow sections.

Figure E.3 — Weld preparation and fit-up - Fillet welds in circular hollow section brace to chord joints



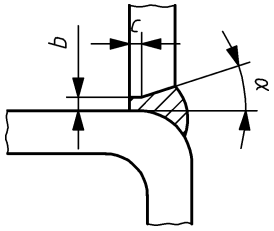
Detail at A, B:



where $b_1 < b_0$

b = 2 mm to 4 mm

c = 1 mm to 2 mm



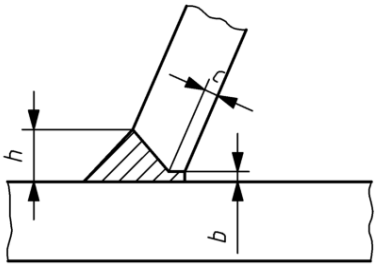
where $b_1 = b_0$

b = 2 mm max.

c = 1 mm to 2 mm

α = 20° to 25°

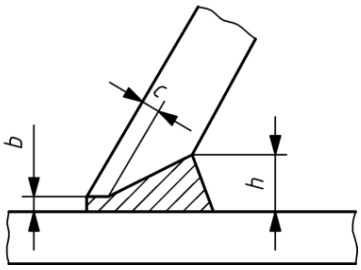
Detail at C:



b = 2 mm to 4 mm

c = 1 mm to 2 mm

Detail at D:



θ = 60° to 90°

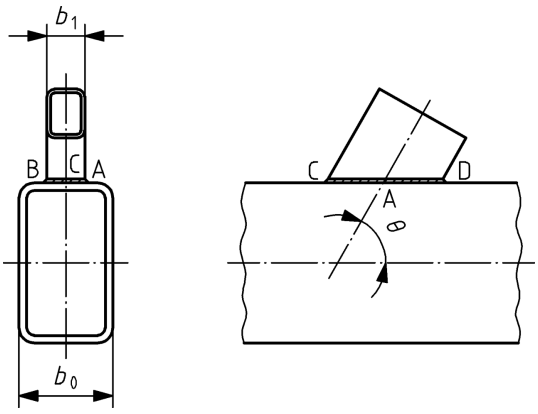
b = 2 mm to 4 mm

c = 1 mm to 2 mm

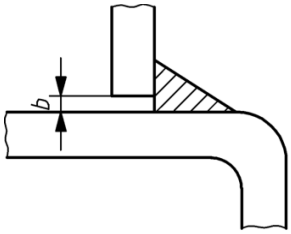
For θ < 60°, a fillet weld detail (as Figure E.5) is preferred to the detail at D in the heel area

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



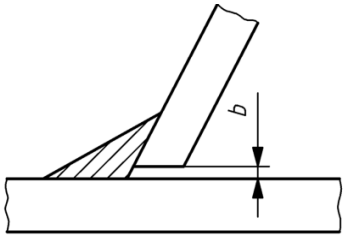
Detail at A, B:



where $b_1 < b_0$

b = max. 2 mm

Detail at C:

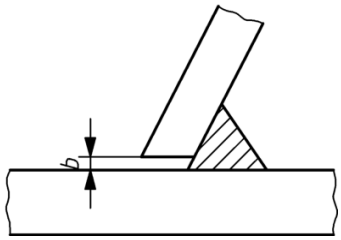


$60° \leq \theta < 90°$

b = max. 2 mm

For θ < 60°, a butt weld detail (as Figure E.4) should be used at C in the toe area.

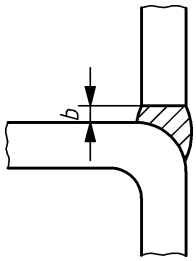
Detail at D:



$30° \leq \theta < 90°$

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

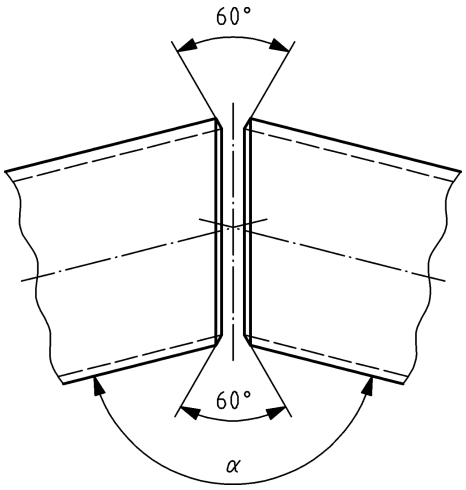
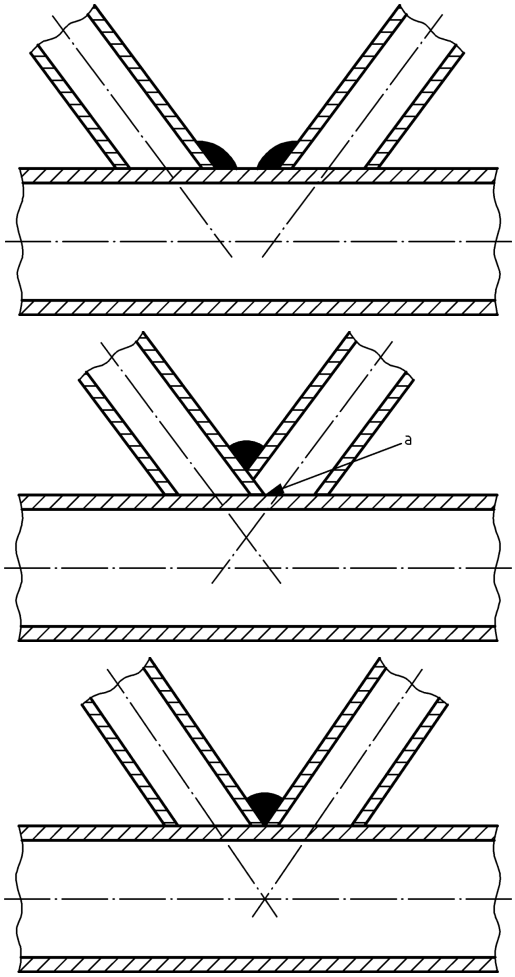


Figure E.6 — Weld preparation and fit-up for hollow section mitre joints



Separate components
Non-overlapping welds
PREFERRED DETAIL
Case A

a = Hidden toe area.
Hidden toe area that shall be welded 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:

— 25 % of the thickness of the thinner constituent product for material ≤ 12 mm thick;

— 3 mm for material over 12 mm thick.

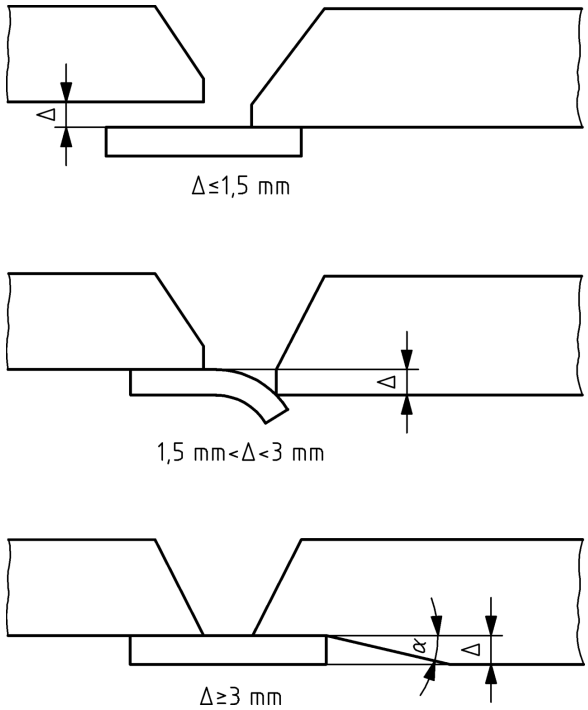
This alignment may be achieved using machining of ends to correct wall thickness variations and ovality or out-of-squareness of hollow sections, provided that the remaining material thickness complies with the minimum specified.

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);

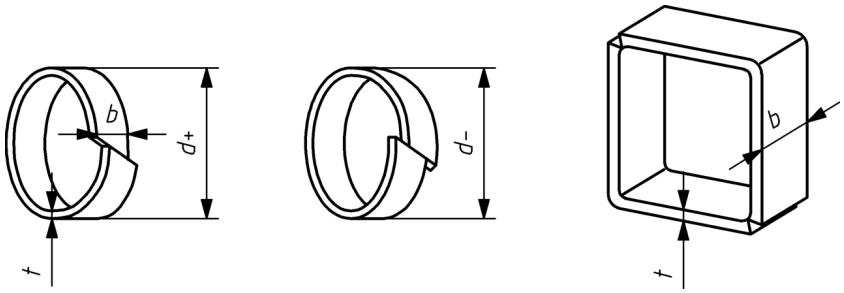
c) if the difference exceeds 3 mm the wall of the thicker component should be tapered with a slope of 1 in 4 or less.



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

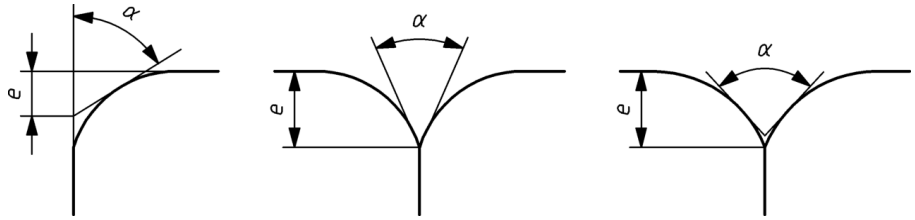
Figure E.9 — Suitable shapes for backing rings or strips

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, *e*, 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.1General

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 hot dip galvanizing. Cathodic protection is not included.

The requirements for corrosion protection shall be given in the execution specification in terms of a performance specification (as F.1.2) or as prescriptive requirements for the protective treatment to be used (as F.1.3).

NOTE 1 EN ISO 12944-8 gives guidelines for developing specifications for corrosion protection using paints and related products applied to plain or hot dip galvanized steel substrates (i.e. duplex coatings). EN ISO 1461, EN ISO 14713-1 and EN ISO 14713-2 give guidance for developing specifications for corrosion protection using hot dip galvanizing. EN 13438 and EN 15773 give guidance on powder coating of hot dip galvanized steel.

NOTE 2 Guidance on thermal spraying is given in EN ISO 2063.

This Annex does not cover the corrosion protection of cables and fittings.

NOTE 3 See EN 1993–1–11:2006, Annex A.

F.1.2 Performance specification

If a performance specification is used to specify the requirements for corrosion protection, it shall specify:

a) the expected life of the corrosion protection (see EN ISO 12944-1 and EN ISO 14713-1:2017, Table 2) and;

b) the corrosivity category (see EN ISO 12944-2 and EN ISO 14713-1:2017, Table 1).

The performance specification may also state a preference for painting, thermal spraying or hot dip galvanizing.

NOTE In terms of performance, the EN ISO 4628 series can be used for assessing degradation of paints and related products.

F.1.3 Prescriptive requirements

If the expected life of a corrosion protection and corrosivity category are specified in accordance with F.1.2, 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 ISO 12679 and F.2.1);

c) surface preparation for manufactured steel components to be hot dip 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) hot dip galvanizing (see F.6.3);

i) particular requirements for inspection and checking (see F.7);

j) special requirements for bimetallic interfaces.

F.1.4 Work method

Corrosion protection shall be undertaken in accordance with work methods that are based on a quality plan, if required, and that comply with F.2 to F.7 as relevant. If required, 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.

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.

Environmental conditions for the work shall be maintained 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.

Repair procedures shall be appropriate to the damage incurred using handling, storage and erection procedures and shall be in accordance with product manufacturer's recommendations.

F.2Surface preparation of carbon steels

F.2.1 Surface preparation of carbon steels prior to painting or metal spraying

Surfaces shall be prepared in accordance with 10.2 and 12.6.

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 Hand/power tool cleaning 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 sweep blasting 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.

F.2.2 Surface preparation of carbon steels prior to hot dip galvanizing

Surfaces shall be prepared in accordance with 10.5, EN ISO 14713-2 and EN ISO 1461, unless otherwise specified.

NOTE With pickling used prior to hot dip galvanizing, high strength steels may become susceptible to hydrogen-inducing cracking, strain age embrittlement, liquid metal assisted cracking or liquid metal embrittlement. (see EN ISO 14713-2).

F.3Welds 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.4Surfaces 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 bolting assemblies shall be specified. If the contact surfaces are to be painted before assembly, only primer coating shall be applied with a maximum dry coating thickness of 100 μm.

F.5Preparation 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.6Coating methods

F.6.1 Painting

The surface condition of the component shall be checked just before painting to ensure that it complies with the required specifications, EN ISO 12944-4, the EN ISO 8501 series 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.

Work shall not proceed if the environmental and surface conditions are not in accordance with the product manufacturer's recommendations.After application, painted surfaces shall be protected for a period after application as required by the product manufacturer's recommendations.

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 Hot dip galvanizing

Hot dip galvanizing shall be undertaken in accordance with EN ISO 1461.

If hot dip galvanizing after manufacturing is specified for cold formed components, it shall be undertaken in accordance with EN ISO 1461 and requirements for procedure qualification of the dipping process shall be specified.

Requirements for the inspection, checking or qualification of the preparation to be carried out before subsequent overcoating shall be specified.

F.7Inspection and checking

F.7.1 General

Inspection and checking shall be undertaken in accordance with the quality plan, if required, 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 10.2 and 12.6;

b) thickness measurement of:

1) each layer of the paint coating in accordance with ISO 19840, but when protection is achieved by hot dip galvanizing, the paint coating shall be checked in accordance with EN ISO 2808;

2) thermal spraying in accordance with EN ISO 2063;

3) hot dip galvanizing in accordance with EN ISO 1461;

c) visual inspection that paint treatment complies with the provisions of EN ISO 12944-7;

d) unless otherwise specified, for paint treatment the extent of checking shall be:

3) five dry film thicknesses (DFT) readings shall be taken for every 100 m^2 of each layer of coating;

2) the average of these five readings shall not be less than the specified nominal DFT (NDFT);

3) the minimum of these five readings shall not be less than 80 % of the NDFT;

4) the maximum of these five readings shall not exceed 2 x NDFT generally or 3 x NDFT for edges, welds and other areas that receive stripe coating.

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 Hot dip galvanized components

Unless otherwise specified, due to the risk of liquid metal assisted cracking (LMAC), hot dip galvanized components shall be subjected to post-galvanizing inspection.

NOTE Information on LMAC is given in [39], [40], [42] and [43].

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)

Determination of 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) number and configuration of washers;

h) grade of steel plates.

G.3 Test specimens

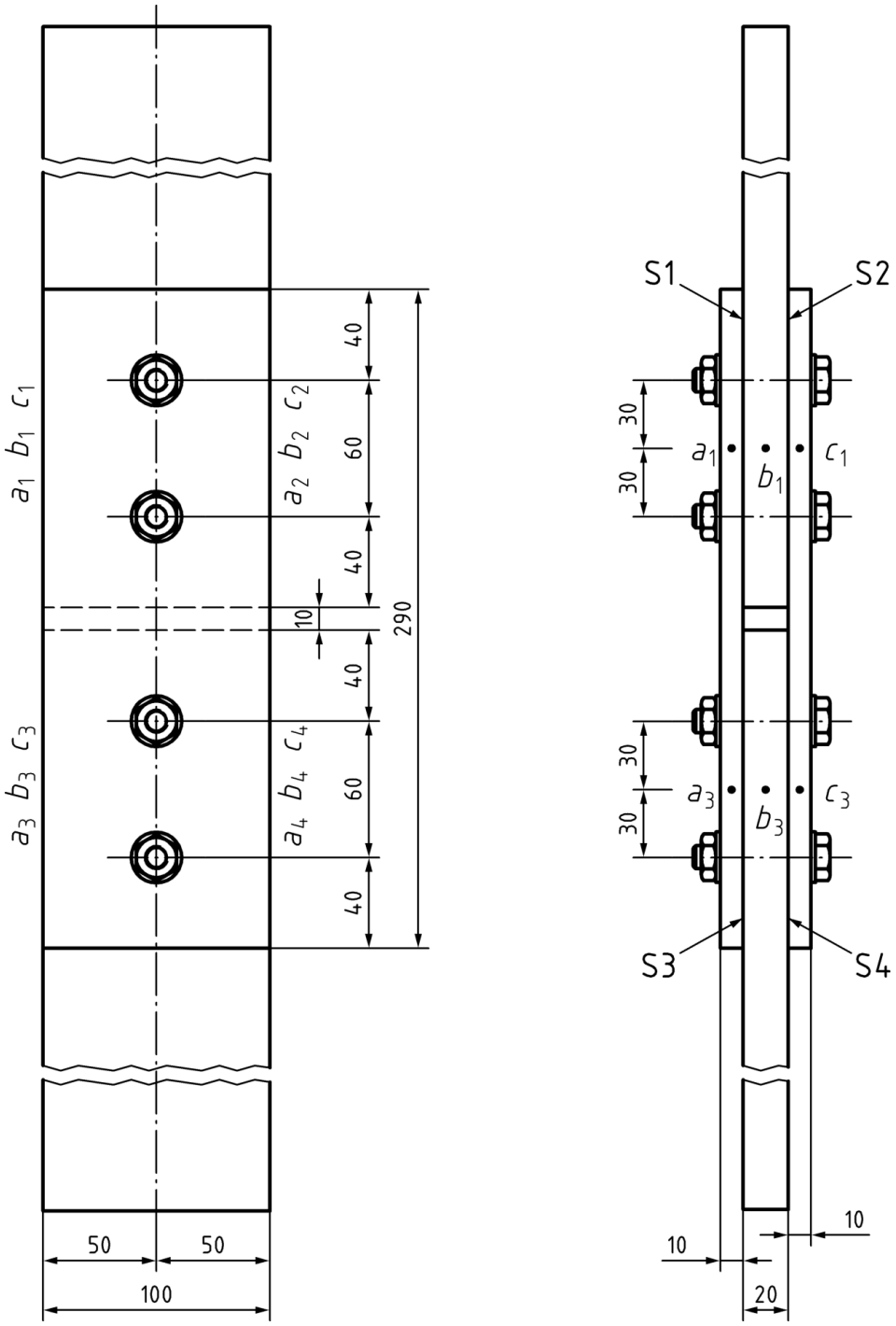
The test specimens shall conform to the dimensional details shown in Figure G.1.

The steel material shall conform to EN 10025-2 to EN 10025-6 and stainless steels according to EN 10088-4 or EN 10088-5.

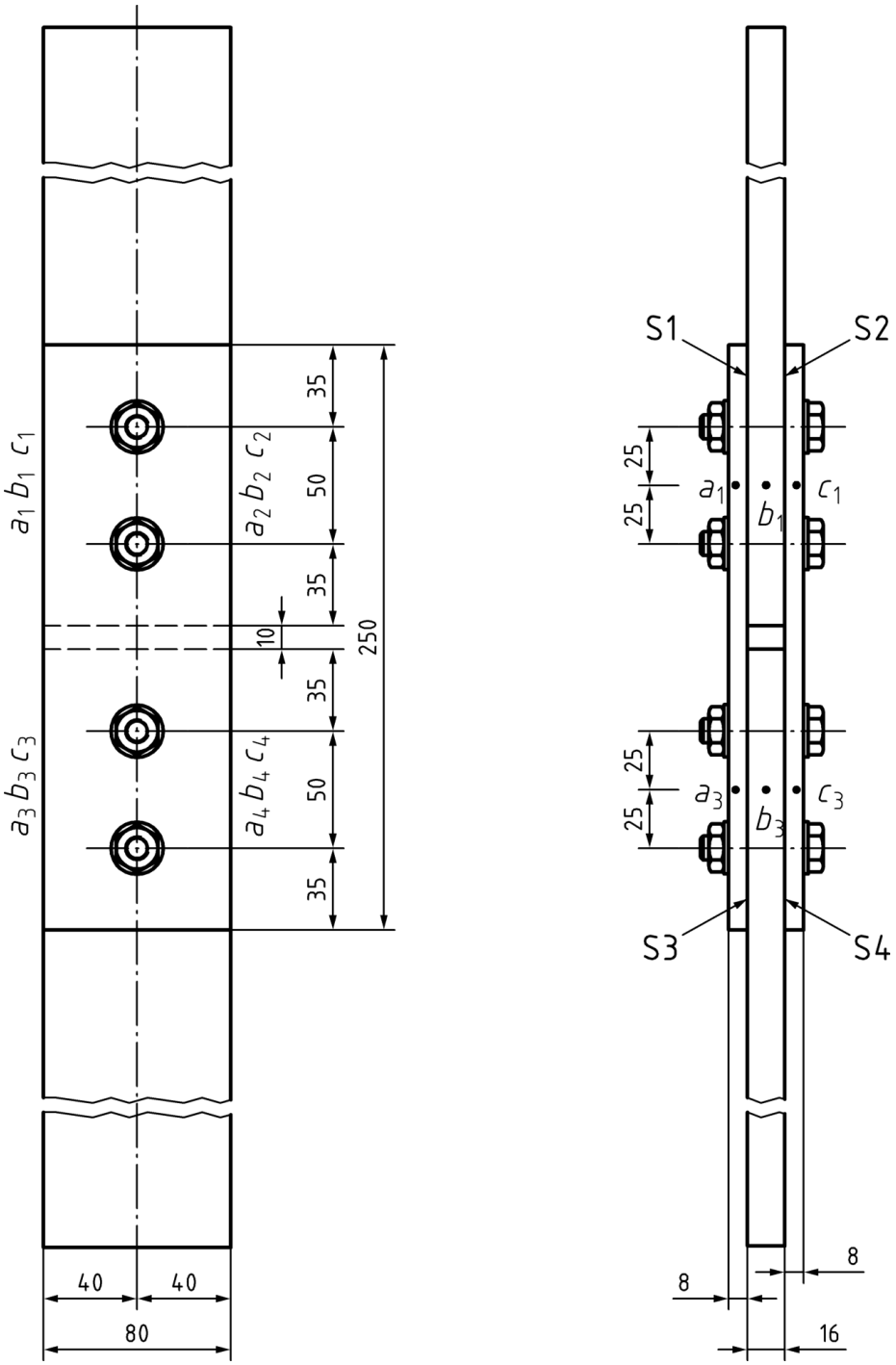
To ensure that the two inner plates have the same thickness, they shall be produced by cutting them consecutively from the same piece of material and assembled in their original relative positions.

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 hole diameter



b) M16 bolts in 18 mm hole diameter

Key

S1 Slip plane 1
S2 Slip plane 2
S3 Slip plane 3
S4 Slip plane 4

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 ± 4 %.

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.

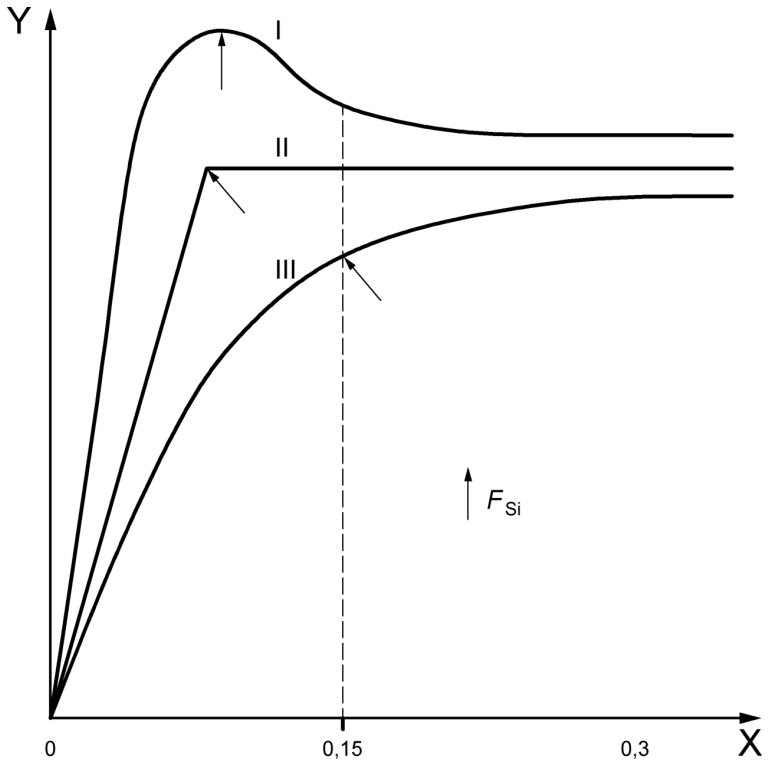
The specimens shall be tested in a tension-loading machine. The load-slip relationship shall be recorded.

In a test specimen, four slip planes exist: slip planes 1 to 4 according to Figure G.1.

The slip shall be taken as the relative displacement between adjacent points on an inner plate (position b, Figure G.1) and a cover plate (positions a and c, Figure G.1), in the direction of the applied load. It shall be measured for each end and each side of the specimen separately resulting in eight displacement values, see Figure G.1.

Slip may occur in a failure mode of combination of slip in slip planes 1 and 2, 3 and 4 or diagonal in slip planes 1 and 4 or 2 and 3. The slip has to be evaluated according to the existing failure mode, so that finally two mean slip values are determined on the basis of eight measured displacements.

The individual slip load for a connection, F_{Si}, is defined as the load at 0,15 mm displacement or at the peak load before 0,15 mm displacement according to the load-displacement diagram as given in Figure G.2.



Key

X slip displacement [mm]

Y force, F_{Si}

NOTE I Slip load is the peak load before slip of 0,15 mm.

II Slip load is load at sudden slip before 0,15 mm

III Slip load is the load at slip of 0,15 mm.

Figure G.2 — Definition of the slip load for different load-displacement behaviour

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:

$$n > (s / 3{,}5)^2 \quad \text{(G.1)}$$

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.

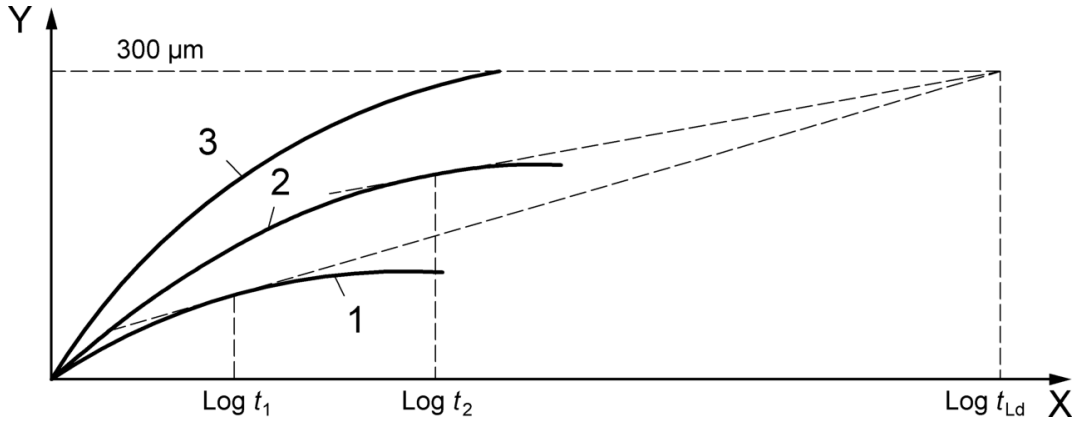
G.5 Extended creep test procedure and evaluation

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.

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 16.

A "displacement - log time" curve shall be plotted (see Figure G.3) 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.



Key

X time (log-scale)

Y slip displacement

NOTE t_{Ld} Design life of structure

t_1 Minimum duration for test 1

t_2 Minimum duration for test 2

Curve 1 Passed extended creep test.

Curve 2 Passed extended creep test.

Curve 3 Extended creep test is not passed.

Figure G.3 — Use of the displacement - log time curve for extended creep test

G.6 Test results

Individual slip factor values are determined as follows:

$$\mu_i = \frac{F_{Si}}{4F_{p,C}} \qquad \text{(G.2)}$$

The slip load mean value F_{Sm} and its standard deviation s_{F_S} are determined as follows:

$$F_{Sm} = \frac{\sum F_{Si}}{n}, \quad s_{Fs} = \sqrt{\frac{\sum \left(F_{Si} - F_{Sm}\right)^2}{n-1}} \tag{G.3}$$

The slip factor mean value μ_m and its standard deviation s_μ are determined as follows:

$$\mu_m = \frac{\sum \mu_i}{n}, \quad s_\mu = \sqrt{\frac{\sum \left(\mu_i - \mu_m\right)^2}{n-1}} \tag{G.4}$$

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 G.4 or G.5 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)

Calibration test for preloaded bolting assemblies under site conditions

H.1 General

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.

The purpose of this test is not to upgrade the properties of a bolting assembly declared in accordance with EN 14399-1.

H.2 Symbols and units

A_s	nominal stress area of the bolt, (mm^2) (see EN ISO 898-1);
e_M	ratio $e_M = (M_{max} - M_{min})/M_m$;
F_b	bolt force determined during the test (kN);
F_m	mean value of the i number $F_{b,i}$ test values for F_b (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 $F_{p,C}$ (Nm);
M_m	mean value of the i number M_i values (Nm);
M_{max}	maximum value of the i number M_i values (Nm);
M_{min}	minimum value of the i number M_i values (Nm);
$M_{r,test}$	torque reference value (Nm) (see 8.5.2 b));
s_M	estimated standard deviation of the i number M_i values (kN);
V_M	coefficient of variation of the i number M_i values;
V_F	coefficient of variation of the i number $F_{b,i}$ values;
$\theta_{p,i}$	individual value of the angle θ at which the bolt force has first reached the value of $F_{p,C}$ (°);
$\theta_{1,i}$	individual value of the angle θ at which the bolt force has reached its maximum value $F_{b,i,max}$ (°);
$\theta_{2,i}$	individual value of the angle θ at which the test is stopped (°);
$\Delta\theta_{1,i}$	the individual angle difference ($\theta_{1,i} - \theta_{p,i}$) (°);
$\Delta\theta_{2,i}$	the individual angle difference ($\theta_{2,i} - \theta_{p,i}$) (°);

$\Delta\theta_{2,min}$ the minimum required value of the angle difference $\Delta\theta_{2,i}$ as specified in the relevant product standard (°).

H.3 Principle of the test

The test has the possibility to measure the following parameters during tightening:

— the bolt force;

— the torque, if required;

— 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 H.8. 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 requirement for the wrenches is ± 4 % for the torque method or ± 10 % for the combined method as appropriate. 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.

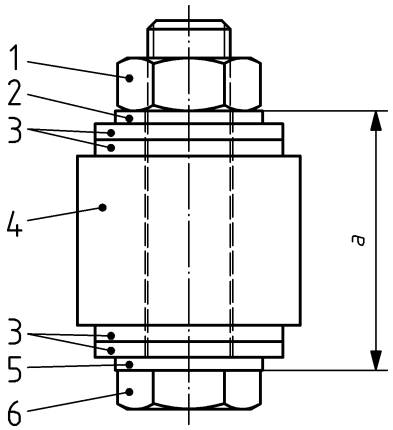
The test assemblies and shims shall be positioned such that:

— the composition of the assembly is similar to the utilization 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:

a clamb length Σt
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

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 associated with the bolt forces $F_{b,i}$ and to relate those values to target preload tension in the bolt as a proportion of $F_{p,C} = 0,7\, f_{ub}\, A_s$.

For the torque method, the test shall be terminated when any one of the following conditions is satisfied:

a) the bolt force exceeds 1,1 $F_{p,C}$;

b) the angle of nut rotation exceeds ($\theta_{p,i} + \Delta\theta_1$) and/or ($\theta_{p,i} + \Delta\theta_{2,min}$), if required;

c) bolt failure by fracture occurs.

H.8 Evaluation of test results

The criteria for allowable maximum torque values for the combined method are given in Table H.1 where the measured torque values M_i are determined by preloading in one set of bolts assemblies to the exact value of 0,75 $F_{p,C}$.

Table H.1 — Maximum values for e_M for the combined method

Number (i) 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 %.				

The acceptance criteria for the torque method shall be based on eight measured torque values $M_{1\text{-}8}$ determined by preloading in one set of eight bolting assemblies to the exact value of 1,10 $F_{p,C}$.

The resulting torque moment $M_{r,test}$ for preloading based on all eight of these tests shall be taken as

$$M_{r,test} = (M_{max} + M_{min.}) / 2 \quad \text{(H.1)}$$

with the requirement that

$$(M_{max.} - M_{min.}) \leq 0{,}20\ M_{r,test} \quad \text{(H.2)}$$

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 the EN 14399 series for the fasteners in the assembly lot.

NOTE 1 The rotations $\Delta\theta_1$ and $\Delta\theta_2$ are shown in EN 14399–2:2015, Figure 2.

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.

The acceptance criteria for the HRC method shall be based on the preload from eight bolts after the fracture of the spline-ends.

The following requirements apply:

a) individual value of $F_b \geq F_{p,C}$;

b) mean value $F_m \geq 1{,}1\ F_{p,C}$;

c) coefficient of variation of $F_{b,i}$ $V_F \leq 0{,}06$.

The acceptance criteria for the DTI method shall be based on measuring the preload on eight bolts when the deformations of the indicator protrusions have just reached the values given in EN 14399-9.

The following requirement applies for all eight sample values of $F_{b,i}$:

$$F_{p,C} \leq F_{b,i} \leq 1{,}2\ F_{p,C}$$

NOTE 2 Values for $F_{p,C}$ are given in Table 18.

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;

— calibration certificates for torque wrenches and calibrated force measuring devices.

The test report shall be signed and dated.

Annex I
(informative)

Determination of loss of preload for thick surface coatings

I.1 General

For preloaded bolted connections, contact surfaces on which the coatings applied to each surfaces are thicker than 100 μm or consist of a particularly creep-prone material the potential loss of preload should be checked.

As appropriate, Table I.1 may be used as a reference basis to check the suitability of the surface coatings and to estimate the potential loss of preload. The paint system designations used in Table I.1 are as specified in EN ISO 12944-5. Table I.1 assumes that the coated surfaces on three plies are drawn together by preloaded fasteners with all surfaces coated (i.e. six coated surfaces are pressed together including the outer surfaces below the washers or nuts or bolt heads). The limits on coating thicknesses assumed in Table I.1 are that the dry film thicknesses (DFT) of the tested samples are within the range of nominal DFT ± 20 %.

NOTE 1 The maximum DFT of 1,2 × NDFT is a more restrictive limit than that specified in F.7.2.

Otherwise, a test may be undertaken according to I.2. The purpose of the test is to relate the loss of preload to the maximum permitted thickness of coating layers.

It is not the purpose of the test to assess the effect on the friction coefficient of paint on the faying surfaces of slip resistant preloaded connections.

NOTE 2 The potential loss of preloading force of no more than 10 % is considered in the tightening methods specified in 8.5.

Table I.1 — Potential loss of preload from coatings/coating systems in combination with preloaded contact surfaces

Coating/coating system (See EN ISO 12944-5 **for full system details)**	**System reference in** EN ISO 12944-5	**Potential loss of preload**
Unpainted hot dip galvanizing according to EN ISO 1461	n/a Listed as a reference value	Loss of preload force ≤ 10 % Suitable in all preloaded bolted connections [a] [b]
Alkali metallic zinc silicate primer	n/a	Loss of preload force ≤ 10 % Suitable in all preloaded bolted connections [a] [b]
One layer 2 pack-EP or -PUR coating with Zn(R)	A 3.10	
Multilayer 1 pack-PUR coating systems with Zn(R)	A 3.11 A 4.13 A 4.14 A 4.15	Loss of preload force ≤ 30 %. Suitable in Category A and D bolted connections according to EN 1993–1–8 that are preloaded for serviceability reasons (e.g. durability or deformation minimization)
PVC/PVC-combined coatings with any thickness AK-coatings or AY-Hydro-coatings with thicknesses of more than 120 µm	n/a	Loss of preload force > 30 %. Not suitable for components in preloaded connections

[a] Suitability for friction surfaces see Table 17

[b] In Category B, C and E bolted connections according to EN 1993–1–8 it may be necessary to conduct the structural design with 0,9 $F_{p,C}$ or (in case of the torque method) to specify preloads and bolting assemblies that can be re-tightened after a couple of days

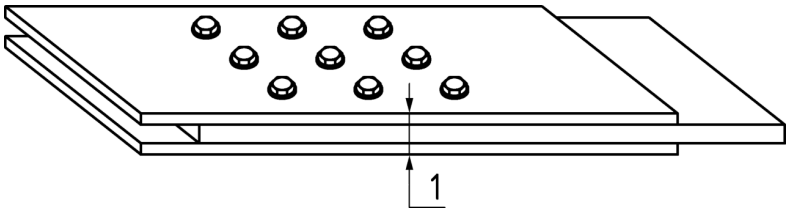
I.2 Test procedure

For coatings/coating systems not listed in Table I.1, or if more than two coated components are pressed together, procedure tests should be conducted to evaluate the potential loss of preloading.

If more than three plies or coated shims are used the potential loss may be assessed based from Table I.1 considering the total number of coated surfaces included in the preloaded connection.

The following procedure is proposed:

a) Test specimens should be 2 plies 170 mm x 170 mm x 10 mm and 1 plie 170 mm x 170 mm x 20 mm with 9 evenly spaced through-holes of 18 mm diameter (see Figure I.1);



Key

1 clamped length

Figure I.1 — Example of test specimen

b) The test plies shall be coated with the coating system on both sides;

c) The plies should be fastened together using 9 preloaded M16 × 70 mm bolt/nut/washer assemblies that are hot dip galvanized according to EN ISO 10684;

d) The fasteners should be preloaded according to the relevant method given in 8.5;

e) The loss of preload should be assessed based on the change in length of the clamped length of the bolting assembly over a period of at least 30 days.

The test results should be documented.

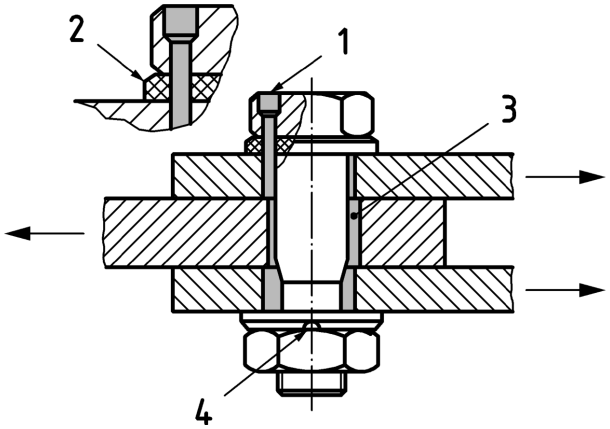
Annex J
(informative)

Resin injection bolts

J.1 General

This Annex provides information on the supply and use of resin 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 by injecting resin through a small hole in the head of the bolt as shown in Figure J.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 J.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 ECCS No 79.

J.2 Hole sizes

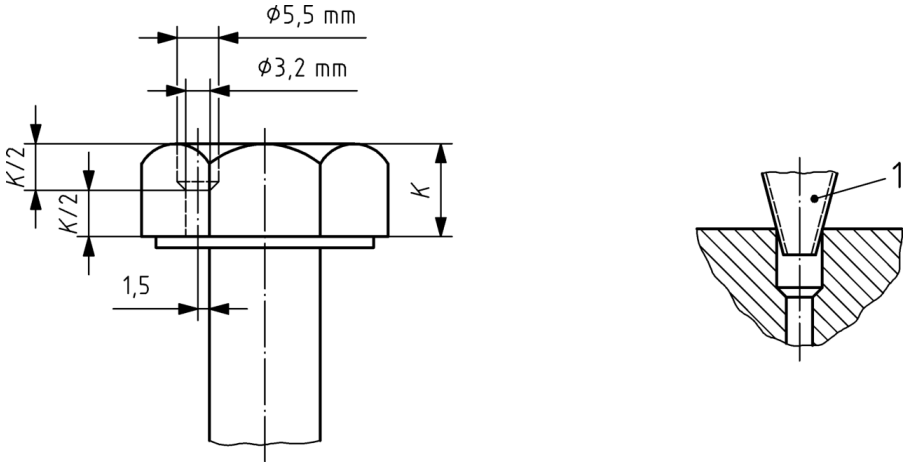
The nominal clearance for bolts in the hole should be 3 mm. For bolts smaller than M27, the clearance may be reduced to the clearance of 2 mm, as specified in 6.6 for normal round holes.

J.3 Bolts

The head of the bolt should be provided with a hole having a position and dimensions as specified in Figure J.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

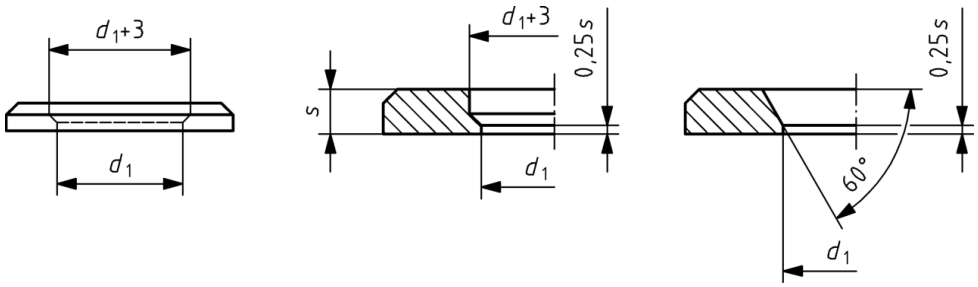
1 nozzle of injection device

Figure J.2 — Hole in the head of the bolt

J.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 J.3 a) or J.3 b) in which the dimensions are in mm.

Dimensions in millimetres



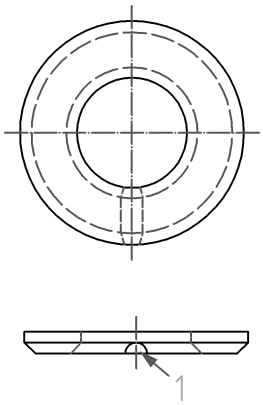
a) Drilled b) Chamfered

Figure J.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 J.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 J.4 — Preparation of the washer for use under the nut

J.5 Nuts

The nuts may be assumed to be sufficiently secured by the resin.

J.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.

J.7 Tightening

Tightening of the bolts in accordance with Clause 8 should be carried out before starting the injection procedure.

J.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 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.

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 K
(informative)

Guide to flow diagram for development and use of a WPS

Table K.1 — Flow diagram for development and use of a WPS

Development of a preliminary p**WPS**
↓
Qualification of the welding procedure by a method according to 7.4.1 **(WPQR)**
↓
Preparing the **WPS** for production based on the relevant welding procedure qualification record (**WPQR)**
↓
Use of the **WPS** for the first 5 welds in production with **NDT** extent according to 12.4.2.2
↓
Use of the **WPS** after the first 5 welds in production with **NDT** extent according to 12.4.2.3

Annex L
(informative)

Guidance on the selection of weld inspection classes

L.1 General

Specification of EXC may not always be sufficient alone for the differentiation of the acceptance criteria and the extent of inspection for welds /details of different importance or criticality. This may result in the following:

a) the acceptance criteria may become too onerous for welds that are not important;

b) the extent of specified inspection may become too large for welds that are not important;

c) the specified inspection may miss the critical locations.

The use of weld inspection classes (WICs) may be useful in directing the scope and percentage extent of supplementary testing according to the criticality of the weld. This may be beneficial both from a safety aspect and from an economic point of view as unnecessary inspection and repair may be avoided.

The initial choice of weld inspection classes (WICs) should take into account the likelihood that defects would arise for particular weld configurations (e.g. welds to be executed in difficult conditions such as overhead welds, site welds, welds for temporary attachments). Subsequently, the weld inspection classes (WICs) may be reduced or re-instated based on experience in production. This experience should be reviewed separately for each welding process and production location.

L.2 Selection criteria

If weld inspection classes are to be used then Table L.1 provides guidance on a systematic method for the selection of weld inspection classTable L.1 is based on the following criteria for selection:

a) utilization for **fatigue**;

b) **consequence** of failure of weld for the structure;

c) direction, type and level of **stresses**.

Table L.1 — Guidance on a method for selection of weld inspection class

Level of fatigue utilization [a]	**Consequences from failure of joint or component** [c]	**Stress in weld** [b]	**Weld Inspection Class (WIC)**
High fatigue utilization	Substantial [b]	Welds with the direction of dynamic principal stress transverse to the weld (between 45° and 135°)	WIC5
		Welds with the direction of dynamic principal stress in the direction of the weld (between –45° and +45°)	WIC4
	Not substantial [c]	Welds with the direction of dynamic principal stress transverse to the weld (between 45° and 135°)	WIC3
		Welds with the direction of dynamic principal stress in the direction of the weld (between –45° and +45°)	WIC2
No fatigue (i.e. quasi-static) or **Low** fatigue utilization	Substantial [b]	Welds with high [d] tensile stresses transverse to weld	WIC5
		Welds with low tensile stresses transverse to weld and/or high [d] shear stresses	WIC4
	Not substantial [c]	For welds in EXC3 or EXC4 with high [d] tensile stresses transverse to weld	WIC3
		All other load-bearing welds except welds in EXC1	WIC2
		Welds in EXC1 and non-load-bearing welds	WIC1

[a] Low fatigue utilization means connection with calculated fatigue life longer than 4 times the required fatigue life.

[b] Substantial consequences means that the failure of the joint or member will entail:

- possible multiple loss of human life; and/or;
- significant pollution; and/or;
- major financial consequences.

[c] The consequences may be assessed as Not substantial if the structure has been provided with sufficient residual strength to meet specified accidental actions.

[d] High stresses are those that (quasi-)static stresse that exceed 50 % of the welds tensile or shear capacity, as appropriate. Low stresses conversely. Special consideration should also be given to the selection of WIC where the principal stress is in the through-thickness direction of the parent material.

L.3 Extent of supplementary testing

Table L.2 specifies the extent and method of supplementary testing related to weld inspection classes.

Table L.2 — Percent extent of supplementary testing according to WIC

Weld Inspection Class (WIC)	Type of joint	RT	UT	MT/PT
WIC5	Full penetration in-line butt weld	10	100	100
	Full penetration T-butt weld	0	100	100
	Partial penetration welds with penetration depth greater than 12 mm	0	20	100
	Other partial penetration welds and all fillet welds	0	0	100
WIC4	Full penetration in-line butt weld	5	50	100
	Full penetration T-butt weld	0	50	100
	Partial penetration welds with penetration depth greater than 12 mm	0	10	100
	Other partial penetration welds and all fillet welds	0	0	100
WIC3	Full penetration in-line butt weld	0	20	20
	Full penetration T-butt weld	0	20	20
	Partial penetration welds with penetration depth greater than 12 mm	0	5	20
	Other partial penetration welds and all fillet welds	0	0	20
WIC2	Full penetration in-line butt weld	0	10	10
	Full penetration T-butt weld	0	10	10
	Partial penetration welds with penetration depth greater than 12 mm	0	5	5
	Other partial penetration welds and all fillet welds	0	0	5
WIC1	All joint types	0	0	0

Annex M
(normative)

Sequential method for fasteners inspection

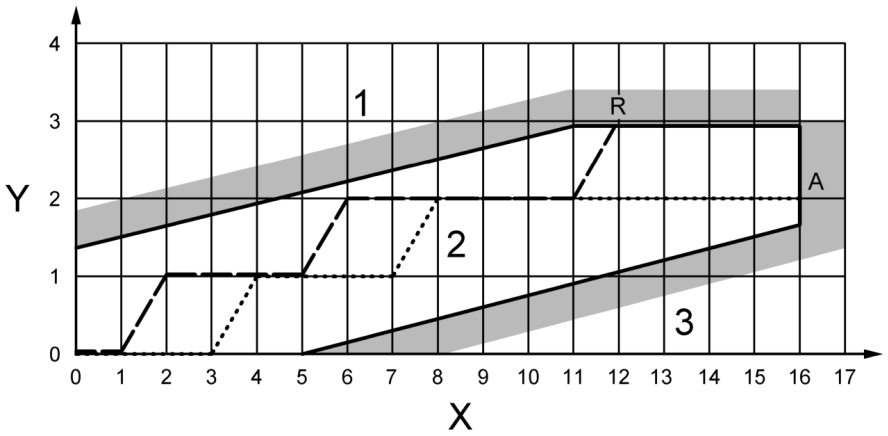
M.1 General

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

X	number of fasteners inspected	EXAMPLES:
Y	number of defective fasteners	DotDashed line: The 2nd, 6th and 12th fasteners were found defective. Exit from the indecision zone is into the rejection zone. The result is ”rejection”
1	rejection zone	
2	indecision zone	Dashed line: The 4th and 8th fasteners were found defective. Inspection was continued until crossing the vertical curtailment line. The result is ”acceptance”
3	acceptance zone	

Figure M.1 — Example of sequential inspection diagram

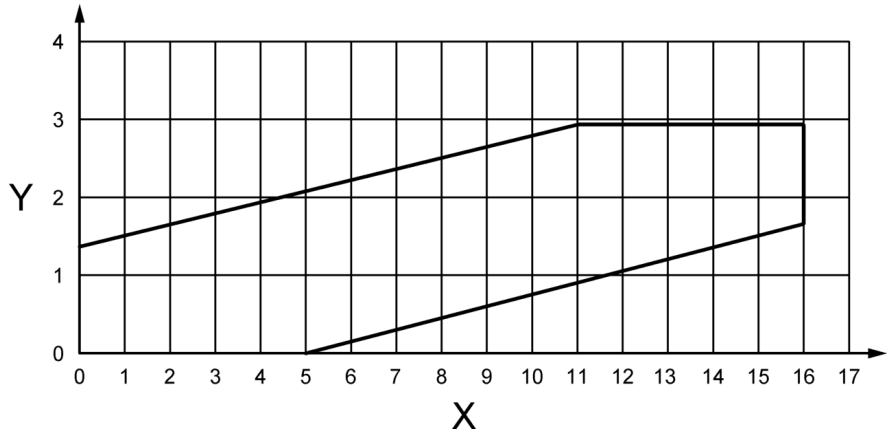
M.2 Application

The following diagrams, Figure M.2 (sequential type A) and Figure M.3 (sequential type B) apply as relevant.

a) Sequential type A:

4) minimum number of fasteners to be inspected: 5

maximum number of fasteners to be inspected: 16



Key

X number of fasteners inspected

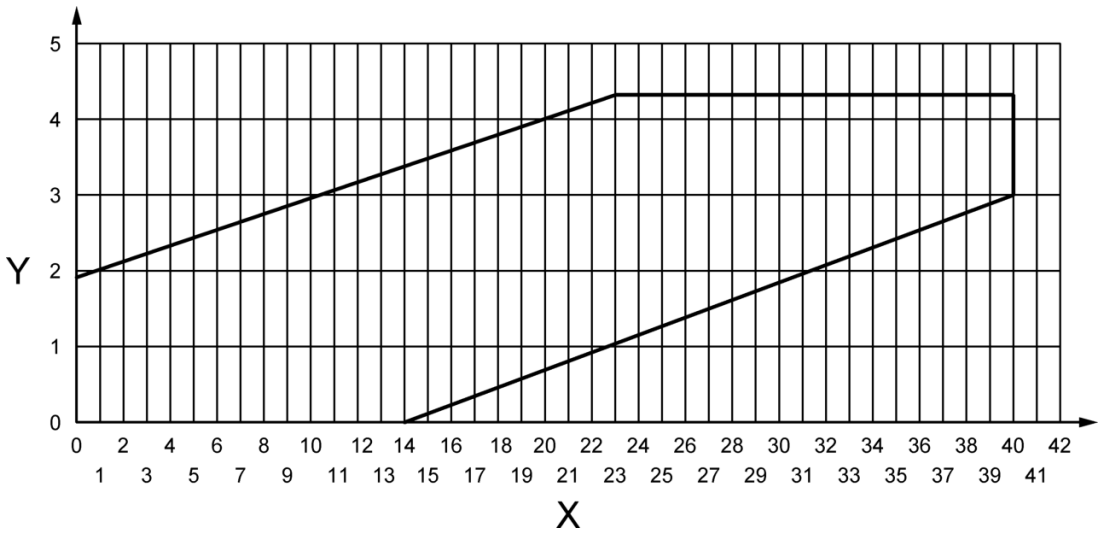
Y number of defective fasteners

Figure M.2 — Sequential type A diagram

b) Sequential type B:

5) minimum number of fasteners to be inspected: 14

maximum number of fasteners to be inspected: 40



Key

X number of fasteners inspected

Y number of defective fasteners

Figure M.3 — Sequential type B diagram

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