

English Version

Execution of steel structures and aluminium structures -
Part 3: Technical requirements for aluminium structures

Exécution des structures en acier et des structures en
aluminium - Partie 3: Exigences techniques pour
l'exécution des structures en aluminium

Ausführung von Stahltragwerken und
Aluminiumtragwerken - Teil 3: Technische
Anforderungen an Aluminiumtragwerke

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 135.

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

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European foreword

This document (prEN 1090-3:2017) 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 document is currently submitted to the CEN Enquiry.

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

This document will supersede EN 1090-3:2008.

The main changes with respect to the previous edition are contained in the following clauses: Clause 1, Clause 2, Clause 3, 4.1.1, 4.1.2, Table 1, Table 5, 5.6.2, 6.1, 7.3, 7.4.1, 7.4.3, 7.4.4, 7.5.1, 7.5.9, 7.5.10, 7.5.11, 7.5.12, 7.5.13, 7.6, 8.3.1, 11.2.3.1, 12.4.2.1, 12.4.2.2, 12.4.3.2, 12.4.4.3, 12.4.5 and 12.7. Annex E has been deleted and the annexes correspondingly renumbered. The main changes in the annexes are contained in the following sub-clauses: E.2.2, Table F.3, I.1, Table I.1, Table I.2, Table K.1, Table K.2 and K.4. Annex N is a new annex. The Bibliography has been revised. In addition to the major changes in the clauses listed above, some editorial changes have been made.

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

Introduction

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

This European Standard specifies requirements for the execution of aluminium structures, in particular those that are designed according to EN 1999-1-1, EN 1999-1-2, EN 1999-1-3, EN 1999-1-4 and EN 1999-1-5.

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.

РАБОТЕН ДОКУМЕНТ

1 Scope

This European Standard specifies requirements for the execution of aluminium structural components and structures made from:

- a) rolled sheet, strip and plate;
- b) extrusions;
- c) cold drawn rod, bar and tube;
- d) forgings;
- e) castings.

NOTE 1 The execution of structural components is referred to as manufacturing, in accordance with EN 1090-1.

This European Standard specifies requirements independent of the type and shape of the aluminium structure, and this European Standard is applicable to structures under predominantly static loads as well as structures subject to fatigue. It specifies requirements related to the execution classes that are linked with consequence classes.

NOTE 2 Consequence classes are defined in EN 1990.

NOTE 3 Recommendations for selection of execution class in relation to consequence class are given in EN 1999-1-1.

This European Standard covers components made of constituent products with thickness not less than 0,6 mm for welded components not less than 1,5 mm.

For components made from cold formed profiled sheeting that are within the scope of FprEN 1090-5, the requirements of FprEN 1090-5 take precedence over corresponding requirements in this European Standard.

This European Standard applies to structures designed according to the relevant parts of EN 1999. If this European Standard is used for structures designed according to other design rules or used for other alloys and tempers not covered by EN 1999, a judgement of the reliability elements in these design rules should be made.

This European Standard specifies requirements for surface preparation prior to application of a protective treatment, and gives guidelines for application for such treatment in an informative annex.

This European Standard gives options for specifying requirements to match project specific requirements.

This European Standard is also applicable to temporary aluminium structures.

2 Normative references

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

EN 485-1, *Aluminium and aluminium alloys — Sheet, strip and plate — Part 1: Technical conditions for inspection and delivery*

EN 485-3, *Aluminium and aluminium alloys — Sheet, strip and plate — Part 3: Tolerances on dimensions and form for hot-rolled products*

EN 485-4, *Aluminium and aluminium alloys — Sheet, strip and plate — Part 4: Tolerances on shape and dimensions for cold-rolled products*

EN 515, *Aluminium and aluminium alloys — Wrought products — Temper designations*

EN 573-1, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 1: Numerical designation system*

EN 573-2, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 2: Chemical symbol based designation system*

EN 573-3, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 3: Chemical composition and form of products*

EN 586-1, *Aluminium and aluminium alloys — Forgings — Part 1: Technical conditions for inspection and delivery*

EN 586-3, *Aluminium and aluminium alloys — Forgings — Part 3: Tolerances on dimensions and form*

EN 754-1, *Aluminium and aluminium alloys — Cold drawn rod/bar and tube — Part 1: Technical conditions for inspection and delivery*

EN 754-3, *Aluminium and aluminium alloys — Cold drawn rod/bar and tube — Part 3: Round bars, tolerances on dimensions and form*

EN 754-4, *Aluminium and aluminium alloys — Cold drawn rod/bar and tube — Part 4: Square bars, tolerances on dimensions and form*

EN 754-5, *Aluminium and aluminium alloys — Cold drawn rod/bar and tube — Part 5: Rectangular bars, tolerances on dimensions and form*

EN 754-6, *Aluminium and aluminium alloys — Cold drawn rod/bar and tube — Part 6: Hexagonal bars, tolerances on dimensions and form*

EN 754-7, *Aluminium and aluminium alloys — Cold drawn rod/bar and tube — Part 7: Seamless tubes, tolerances on dimensions and form*

EN 754-8, *Aluminium and aluminium alloys — Cold drawn rod/bar and tube — Part 8: Porthole tubes, tolerances on dimensions and form*

EN 755-1, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 1: Technical conditions for inspection and delivery*

EN 755-3, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 3: Round bars, tolerances on dimensions and form*

EN 755-4, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 4: Square bars, tolerances on dimensions and form*

EN 755-5, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 5: Rectangular bars, tolerances on dimensions and form*

EN 755-6, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 6: Hexagonal bars, tolerances on dimensions and form*

EN 755-7, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 7: Seamless tubes, tolerances on dimensions and form*

EN 755-8, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 8: Porthole tubes, tolerances on dimensions and form*

EN 755-9, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 9: Profiles, tolerances on dimensions and form*

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

EN 1011-4, *Welding — Recommendations for welding of metallic materials — Part 4: Arc welding of aluminium and aluminium alloys*

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

EN 1301-1, *Aluminium and aluminium alloys — Drawn wire — Part 1: Technical conditions for inspection and delivery*

EN 1301-3, *Aluminium and aluminium alloys — Drawn wire — Part 3: Tolerances on dimensions*

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 1337-8, *Structural bearings — Part 8: Guide Bearings and Restraint Bearings*

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

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

EN 1559-4, *Founding — Technical conditions of delivery — Part 4: Additional requirements for aluminium alloy castings*

EN 1706, *Aluminium and aluminium alloys — Castings — Chemical composition and mechanical properties*

EN 1999-1-1, *Eurocode 9: Design of aluminium structures — Part 1-1: General structural rules*

EN 1999-1-2, *Eurocode 9: Design of aluminium structures — Part 1-2: Structural fire design*

EN 1999-1-3, *Eurocode 9: Design of aluminium structures — Part 1-3: Structures susceptible to fatigue*

EN 1999-1-4, *Eurocode 9: Design of aluminium structures — Part 1-4: Cold-formed structural sheeting*

- EN 1999-1-5, *Eurocode 9: Design of aluminium structures — Part 1-5: Shell structures*
- EN 10204, *Metallic products — Types of inspection documents*
- EN 12020-1, *Aluminium and aluminium alloys — Extruded precision profiles in alloys EN AW-6060 and EN AW-6063 — Part 1: Technical conditions for inspection and delivery*
- EN 12020-2, *Aluminium and aluminium alloys — Extruded precision profiles in alloys EN AW-6060 and EN AW-6063 — Part 2: Tolerances on dimensions and form*
- EN 14399-2, *High-strength structural bolting assemblies for preloading — Part 2: Suitability for preloading*
- EN 14399-3, *High-strength structural bolting assemblies for preloading — Part 3: System HR — Hexagon bolt and nut assemblies*
- EN 14399-4, *High-strength structural bolting assemblies for preloading — Part 4: System HV — Hexagon bolt and nut assemblies*
- EN 14399-5, *High-strength structural bolting assemblies for preloading — Part 5: Plain washers*
- EN 14399-6, *High-strength structural bolting assemblies for preloading — Part 6: Plain chamfered washers*
- EN 14399-7, *High-strength structural bolting assemblies for preloading — Part 7: System HR — Countersunk head bolt and nut assemblies*
- EN 14399-8, *High-strength structural bolting assemblies for preloading — Part 8: System HV — Hexagon fit bolt and nut assemblies*
- EN 14399-10, *High-strength structural bolting assemblies for preloading — Part 10: System HRC — Bolt and nut assemblies with calibrated preload*
- EN 15088, *Aluminium and aluminium alloys — Structural products for construction works — Technical conditions for inspection and delivery*
- EN 28839, *Mechanical properties of fasteners — Bolts, screws, studs and nuts made of non-ferrous metals (ISO 8839)*
- 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 1479, *Hexagon head tapping screws (ISO 1479)*
- EN ISO 1481, *Slotted pan head tapping screws (ISO 1481)*
- EN ISO 2009, *Slotted countersunk flat head screws — Product grade A (ISO 2009)*
- EN ISO 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles (ISO 3452-1)*

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 3834-2, *Quality requirements for fusion welding of metallic materials — Part 2: Comprehensive quality requirements (ISO 3834-2)*

EN ISO 3834-3, *Quality requirements for fusion welding of metallic materials — Part 3: Standard quality requirements (ISO 3834-3)*

EN ISO 3834-4, *Quality requirements for fusion welding of metallic materials — Part 4: Elementary quality requirements (ISO 3834-4)*

EN ISO 4014, *Hexagon head bolts — Product grades A and B (ISO 4014)*

EN ISO 4016, *Hexagon head bolts — Product grade C (ISO 4016)*

EN ISO 4017, *Fasteners — Hexagon head screws — Product grades A and B (ISO 4017)*

EN ISO 4018, *Hexagon head screws — Product grade C (ISO 4018)*

EN ISO 4032, *Hexagon regular nuts (style 1) — Product grades A and B (ISO 4032)*

EN ISO 4034, *Hexagon regular nuts (style 1) — Product grade C (ISO 4034)*

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

EN ISO 4288, *Geometrical product specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture (ISO 4288)*

EN ISO 4762, *Hexagon socket head cap screws (ISO 4762)*

EN ISO 6520-1:2007, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding (ISO 6520-1:2007)*

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

EN ISO 7046-2, *Countersunk flat head screws (common head style) with type H or type Z cross recess — Product grade A — Part 2: Steel screws of property class 8.8, stainless steel screws and non-ferrous metal screws (ISO 7046-2)*

EN ISO 7049, *Cross-recessed pan head tapping screws (ISO/FDIS 7049)*

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

EN ISO 7093-2, *Plain washers — Large series — Part 2: Product grade C (ISO 7093-2)*

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

EN ISO 8062-1, *Geometrical product specifications (GPS) — Dimensional and geometrical tolerances for moulded parts — Part 1: Vocabulary (ISO 8062-1)*

EN ISO 8062-3, *Geometrical Product Specifications (GPS) — Dimensional and geometrical tolerances for moulded parts — Part 3: General dimensional and geometrical tolerances and machining allowances for castings (ISO 8062-3)*

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

EN ISO 9017, *Destructive tests on welds in metallic materials — Fracture test (ISO 9017)*

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

EN ISO 9606-2, *Qualification test of welders — Fusion welding — Part 2: Aluminium and aluminium alloys (ISO 9606-2)*

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

EN ISO 10042:2005, *Welding — Arc-welded joints in aluminium and its alloys — Quality levels for imperfections (ISO 10042:2005)*

EN ISO 10642, *Hexagon socket countersunk head screws (ISO 10642)*

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

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

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

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

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 15614-2, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 2: Arc welding of aluminium and its alloys (ISO 15614-2)*

EN ISO 17636-1, *Non-destructive testing of welds — Radiographic testing — Part 1: X- and gamma-ray techniques with film (ISO 17636-1)*

EN ISO 17636-2, *Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors (ISO 17636-2)*

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

EN ISO 17639, *Destructive tests on welds in metallic materials — Macroscopic and microscopic examination of welds (ISO 17639)*

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

EN ISO 17659, *Welding — Multilingual terms for welded joints with illustrations (ISO 17659)*

EN ISO 18273, *Welding consumables — Wire electrodes, wires and rods for welding of aluminium and aluminium alloys — Classification (ISO 18273)*

EN ISO 25239-2, *Friction stir welding — Aluminium — Part 2: Design of weld joints (ISO 25239-2)*

EN ISO 25239-3, *Friction stir welding — Aluminium — Part 3: Qualification of welding operators (ISO 25239-3)*

EN ISO 25239-4, *Friction stir welding — Aluminium — Part 4: Specification and qualification of welding procedures (ISO 25239-4)*

EN ISO 25239-5, *Friction stir welding — Aluminium — Part 5: Quality and inspection requirements (ISO 25239-5)*

EN ISO/IEC 17024, *Conformity assessment — General requirements for bodies operating certification of persons (ISO/IEC 17024)*

CEN ISO/TS 8062-2, *Geometrical Product Specifications (GPS) — Dimensional and geometrical tolerances for moulded parts — Part 2: Rules (ISO/TS 8062-2)*

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

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

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

ISO 10509, *Hexagon flange head tapping screws*

ISO 17123-1, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 1: Theory*

ISO 17123-3, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 3: Theodolites*

ISO 17123-4, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 4: Electro-optical distance meters (EDM measurements to reflectors)*

ISO 17123-7, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 7: Optical plumbing instruments*

3 Terms and definitions

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

3.1

additional non-destructive testing NDT

NDT techniques which are additional to visual examination, e.g. penetration, ultrasonic or radiographic testing

3.2

component

part of the works, which may itself be an assembly of several smaller components

Note 1 to entry: A component might in itself be a structure.

3.3

constituent products

materials and products with properties which enter into structural calculations or otherwise relate to the mechanical resistance and stability of works and parts thereof and/or their fire resistance including aspects of durability and serviceability

3.4

construction works

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

3.5

constructor

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

3.6

design basis method of erection

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

3.7

erection method statement

documentation describing the procedures to be used to erect a structure

3.8

execution

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

3.9

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

3.10

execution specification

set of documents covering the technical data and requirements necessary to execute a particular structure including those specified to supplement and qualify the rules of this European Standard

Note 1 to entry: The execution specification includes requirements where this European Standard identifies items to be specified.

3.11

manufacturer

any natural or legal person who manufactures a construction product or who has such a product designed or manufactured, and markets that product under his name or trademark

Note 1 to entry: This definition is according to the Construction Products Regulation, CPR (EU 305/2011).

3.12

manufacturing

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

Note 1 to entry: For the manufacturing of components, the execution rules of this European Standard apply.

3.13

preparation

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

Note 1 to entry: A prepared part may in itself be a component.

3.14

service category

category that characterizes a component or structure in terms of the circumstances of its use

3.15

structure

organised combination of connected parts designed to carry loads and provide adequate rigidity

[SOURCE: EN 1990:2002]

3.16

works

parts of the construction works that is the aluminium structure

4 Specifications and documentation

4.1 Execution specification

4.1.1 General

The necessary information and technical requirements for execution of any part of the works shall be agreed and completed before commencement of execution of that part of the works. There shall be procedures for making alterations to previously agreed specifications. The execution specification shall consider the following items:

- a) additional information as listed in Annex A, as relevant;
- b) execution classes required, see 4.1.2;
- c) service category;
- d) options as listed in Annex A;
- e) technical requirements regarding the safety of the works, see Annex J;
- f) quality plan, see 4.2.2;
- g) additional specified execution requirements concerning the functionality;
- h) which of the informative annexes shall apply.

4.1.2 Execution classes

Four execution classes EXC1 to EXC4 are given in EN 1999-1-1, for which the required strictness increases from EXC1 to EXC4.

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

Execution classes may apply to the whole structure, to a part of the structure or to specific details. A single structure may include several execution classes.

Guidance on the choice of execution class is given in EN 1999-1-1.

NOTE 1 See Annex A of EN 1999-1-1:2007.

If no execution class is specified, EXC2 applies.

NOTE 2 The list of requirements related to execution classes is given in Table A.3.

4.1.3 Tolerance types

Two types of geometrical tolerances are defined in 11.1:

- a) essential tolerances;
- b) functional tolerances.

4.1.4 Tolerance class for shell structures

For shell structures, four tolerance classes 1 to 4 are given in EN 1999-1-5, for which the required strictness increases from class 1 to class 4.

The requirements for the tolerance classes for shell structures are given in Annex H.

4.1.5 Testing and acceptance criteria for welding

The amount of testing and the acceptance criteria shall be given in the execution specification.

NOTE Recommendations for the extent of testing are given in Annex K and recommendations for the acceptance criteria are given in 12.4.4.

4.2 Constructor's documentation

4.2.1 Quality documentation

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

- a) the allocation of tasks and authority during the various phases of the project;
- b) the procedures, methods and work instructions to be applied;
- c) an inspection plan specific to the works;
- d) a procedure for handling of changes and modifications;
- e) a procedure for handling of nonconformities, requests for concessions and quality disputes;
- f) any hold points or requirement to witness inspections or tests, and any consequent access requirements.

4.2.2 Quality plan

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

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

It shall include:

- a) a general management document which shall address the following points:
 - review of specification requirements against process capabilities;
 - organization chart and managerial staff responsible for each aspect of the execution;
 - principles and organization arrangements for inspection including allocation of responsibilities for each inspection task;
- b) quality documentation for the execution as defined in 4.2.1. The documentation shall be prepared before execution of the construction step to which they relate;
- c) execution records which are actual records of inspections and checks carried out, or demonstrate qualification or certification of implemented resources. Execution records related to a hold-point that affect continuation of execution shall be produced before the hold-point is released.

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

4.2.3 Safety during erection

Method statements giving detailed work instructions should conform to the recommendations regarding the safety during erection as given in Annex J.

4.2.4 Execution documentation

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

5 Constituent products

5.1 General

Constituent products to be used for the execution of aluminium structures shall correspond to the relevant European Standards listed in the following clauses, EN 15088 or any other relevant European Technical Specification. The constituent products to be used shall be specified.

5.2 Identification, inspection documents and traceability

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

For metallic products, the following inspection documents according to EN 10204 shall be requested, according to the relevant execution classes:

- a) EXC2, EXC3 and EXC4: inspection certificate 3.1;
- b) EXC1: test report 2.2.

For EXC3 and EXC4, constituent products shall be traceable at all stages of execution between delivery and incorporation in the structure.

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

For EXC2, EXC3 and EXC4, if different alloys and/or tempers of a constituent product are in circulation together, each item of material shall be designated with a mark that identifies its alloy and temper.

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

If marking is required, unmarked products shall be treated as nonconforming.

5.3 Parent material

Tables 1 to 3 list standardized alloys and tempers corresponding to EN 1999. The selection of material shall take into account the expected execution procedures. The following particularities should be considered if relevant:

- a) use of material with anisotropic behaviour (including extrusion seam welds in porthole and bridge die profiles);
- b) applying cold forming operation;
- c) applying welding on material some of which might influence the material properties unfavourably in the short transverse direction.

NOTE 1 Where rolled products of the material EN AW-6082 are welded using wire electrodes or rods to EN ISO 18273:— Al 5356 or Al 5556 or Al 5356A (or similar) are stressed in service in tension perpendicular or shear parallel to the rolling plane, the manufacturer of the constituent products will preferably confirm by means of 3.1 certificates that the performance in the short transverse direction is not reduced to an unacceptable degree due to thermal influence. If such confirmation does not exist, the constructor will preferably carry out and evaluate a

welding procedure test according to Annex C for the product to be used. If welding consumables EN ISO 18273:— Al 4043 are used such confirmation is not necessary.

- d) use of heating operations during execution, which might change the material properties, e.g. while stove lacquering;
- e) applying means to secure an appropriate surface condition for decorative treatment.

NOTE 2 For the cases listed above, a communication between supplier and purchaser of the material is recommended at the time of order.

Table 1 — Wrought aluminium alloys – Plates, sheets and extrusions

Alloy according to		Temper according to EN 515
EN 573-1 and 3 Numeric	EN 573-2 and 3 Symbol	
EN AW-3103	EN AW-Al Mn1	H14; H16; H24; H26
EN AW-3004	EN AW-Al Mn1Mg1	H14; H16; H24; H26; H34; H36
EN AW-3005	EN AW-Al Mn1Mg0,5	H14; H16; H24; H26
EN AW-5005	EN AW-Al Mg1(B)	O/H111; H12; H14; H22; H24; H32; H34
EN AW-5005A	EN AW-Al Mg1(C)	O/H111; H12; H14; H22; H24; H32; H34
EN AW-5049	EN AW-Al Mg2Mn0,8	O; H14; H111; H24; H34
EN AW-5052	EN AW-Al Mg2.5	H12; H14; H22; H24; H32; H34
EN AW-5083	EN AW-Al Mg4,5Mn0,7	O/H111; H12; H14; H22; H24; H32; H34; F; H112; H116; H321
EN AW-5383	EN AW-Al Mg4,5Mn0,9	O/H111; H116; H321
EN AW-5454	EN AW-Al Mg3Mn	O/H111; H14; H24; H34
EN AW-5754	EN AW-Al Mg3	O/H111; H14; H24; H34
EN AW-6005A	EN AW-Al SiMg(A)	T6
EN AW-6060	EN AW-Al MgSi	T5; T6; T64; T66
EN AW-6061	EN AW-Al Mg1SiCu	T4; T6; T451; T651
EN AW-6063	EN AW-Al Mg0,7Si	T5; T6; T66
EN AW-6082	EN AW-Al Si1MgMn	T4; T5; T6; T651; T61; T6151; T451
EN AW-6106	EN AW-Al MgSiMn	T6
EN AW-7020	EN AW-Al Zn4,5Mg1	T6; T651
EN AW-8011A	EN AW-AlFeSi(A)	H14; H16; H24; H26

Table 2 — Wrought aluminium alloys – Forgings

Alloy according to		Temper according to EN 515
EN 586 Numeric	EN 586 Symbol	
EN AW-5083	EN AW-Al Mg4,5Mn0,7	H112
EN AW-5754	EN AW-Al Mg3	H112
EN AW-6082	EN AW-Al SiMgMn	T6

Table 3 — Aluminium alloys – Castings (die- or sand-cast)

Alloy^a according to		Temper according to EN 1706
EN 1706 Numeric	EN 1706 Symbol	
EN AC-42100	EN AC-Al Si7Mg0,3	Permanent mould: T6; T64
EN AC-42200	EN AC-Al Si7Mg0,6	Permanent mould: T6; T64
EN AC-43000	EN AC-Al Si10Mg(a)	Permanent mould: F
EN AC-43300	EN AC-Al Si9Mg	Sand cast: T6 Permanent mould: T6; T64
EN AC-44200	EN AC-Al Si12(a)	Sand cast, Permanent mould: F
EN AC-51300	EN AC-Al Mg5	Sand cast, Permanent mould: F
^a Requirements for quality testing of cast parts shall be specified. Guidance is given in EN 1999-1-1.		

5.4 Aluminium products

Aluminium constituent products according to Table 4 produced with aluminium and aluminium alloys according to 5.3 shall be used.

Table 4 — Standards for aluminium products

Product	General provisions / Assessment and test methods	Tolerances
Extruded rods, bars, tubes and profiles	EN 755-1	EN 755-3 Round bars EN 755-4 Square bars EN 755-5 Rectangular bars EN 755-6 Hexagonal bars EN 755-7 Seamless tubes EN 755-8 Porthole tubes EN 755-9 Profiles
Extruded precision profiles	EN 12020-1	EN 12020-2
Cold drawn rods, bars and tubes	EN 754-1	EN 754-3 Round bars EN 754-4 Square bars EN 754-5 Rectangular bars EN 754-6 Hexagonal bars EN 754-7 Seamless tubes EN 754-8 Porthole tubes
Forgings	EN 586-1	EN 586-3
Sheet, strip and plate	EN 485-1	EN 485-3 Hot rolled products EN 485-4 Cold rolled products
Castings	EN 1559-1, EN 1559-4	ISO 8062
Wires	EN 1301-1	EN 1301-3

5.5 Welding consumables

Welding consumable shall conform to the requirements of EN ISO 18273. The combination of parent material and welding consumables shall be specified.

NOTE Recommendations for the choice of consumables are given in EN 1999-1-1.

5.6 Mechanical fasteners

5.6.1 Bolts, nuts and plain washers

The category of bolted connections, product standard, property class and any other requirement, i.e. surface treatment, shall be specified.

Fasteners in accordance with Table 5 shall be used. All parts of high strength fastener assemblies shall be supplied with the same surface treatment if surface treatment is specified.

The elements of a bolted connection (bolt, nut and washer) of Table 5 shall exhibit uniform corrosion resistance characteristics. Hot galvanized bolts and nuts shall be from the same manufacturer to ensure fitting of the thread. The hot galvanization of high strength bolts, nuts and washers shall have been carried out under the responsibility of the manufacturer of those.

Table 5 — Bolt, nut, washer combinations for connection categories

Category of the connection according to EN 1999-1-1	Bolts		Nuts		Washers ^b
	Product standard	Property class	Product standard	Property class	Product standard
A, D	EN ISO 4014 EN ISO 4017	Aluminium according to EN 28839 ^a	EN ISO 4032	Aluminium according to EN 28839 ^a	EN ISO 7091
A, D	EN ISO 4014 EN ISO 4017 EN ISO 4762 EN ISO 2009 EN 15048-1	Stainless steel grade 50 according to EN ISO 3506-1	EN ISO 4032 EN 15048-1	50 according to EN ISO 3506-2	EN ISO 7089 EN ISO 7090
A, D	EN ISO 4014 EN ISO 4017 EN ISO 4762 EN ISO 2009 EN ISO 7046-2 EN 15048-1	Stainless steel grade 70 according to EN ISO 3506-1	EN ISO 4032 EN 15048-1	70 according to EN ISO 3506-2	EN ISO 7089 EN ISO 7090
A, D	EN 15048-1	Stainless steel grade 80 according to EN ISO 3506-1	EN 15048-1	80 according to EN ISO 3506-2	
A, D	EN ISO 4016 EN ISO 4018 EN 15048-1	4.6 according to EN ISO 898-1	EN ISO 4034 EN ISO 4032 EN 15048-1	≤ M16: 5 > M16: 4 or 5 according to EN ISO 898-2	EN ISO 7091 EN ISO 7089 EN ISO 7090
A, D	EN ISO 4014 EN ISO 4017 EN 15048-1	5.6 according to EN ISO 898-1	EN ISO 4032 EN 15048-1	5 according to EN ISO 898-2	EN ISO 7091 EN ISO 7089 EN ISO 7090
A, D	EN ISO 4014 EN ISO 4017 EN ISO 4762 EN ISO 7046-2 EN ISO 10642 EN 15048-1	8.8 according to EN ISO 898-1	EN ISO 4032 EN 15048-1	8 according to EN ISO 898-2	EN ISO 7091 EN ISO 7089 EN ISO 7090
A, D	EN 14399-7	8.8	EN 14399-3	8	EN 14399-5 EN 14399-6
A, D	EN ISO 10642 EN 15048-1	10.9 according to EN ISO 898-1	EN ISO 4032 EN 15048-1	10 according to EN ISO 898-2	EN ISO 7091 EN ISO 7089 EN ISO 7090
A, D	EN 14399-7	10.9	EN 14399-3	10	EN 14399-5 EN 14399-6
A, B, C, D, E	EN 14399-3	8.8	EN 14399-3	8	EN 14399-5 EN 14399-6
A, B, C, D, E	EN 14399-3 EN 14399-10	10.9	EN 14399-3 EN 14399-10	10	EN 14399-5 EN 14399-6

Category of the connection according to EN 1999-1-1	Bolts		Nuts		Washers ^b
	Product standard	Property class	Product standard	Property class	Product standard
A, B, C, D, E	EN 14399-4 EN 14399-8	10.9	EN 14399-4	10	EN 14399-6
NOTE The category of the bolted connections according to EN 1999-1-1 are the following: A – Shear connection, bearing type; B – Shear connection, slip-resistant at serviceability limit state; C – Shear connection, slip-resistant at ultimate limit state; D – Tension connection, connection with non-preloaded bolts; E – Tension connection, connection with preloaded high strength bolts.					
^a Only aluminium materials listed in EN 1999-1-1 shall be used. ^b For oversized and slotted holes, washers according EN ISO 7093-1, EN ISO 7093-2 and EN ISO 7094 can also be used.					

NOTE Standardized products for locking devices are for instance those in EN ISO 2320, EN ISO 7040, EN ISO 7042, EN ISO 7719, EN ISO 10511, EN ISO 10512 and EN ISO 10513.

5.6.2 Studs

Dimensions and shape of studs shall be in accordance with EN ISO 13918.

NOTE See informative Annex N on weld studs connected by arc stud welding with tip ignition.

5.6.3 Rivets

Rivets shall be in accordance with EN 1999-1-1.

In case of aluminium alloys containing copper as alloying element, sufficient corrosion resistance or corrosion prevention according to the exposure conditions should be considered.

5.6.4 Self-drilling and self-tapping screws

Self-drilling screws shall conform to the requirements of EN ISO 15480 and self-tapping screws with the requirements of EN ISO 1481, EN ISO 7049, EN ISO 1479 or ISO 10509.

If self-drilling or self-tapping screws are used for applications similar to fixing of trapezoidal sheeting (i.e. fixing thin material parts on a thick substructure), it is necessary to predrill holes if the thickness of the component to be fixed exceeds 2 mm or use screws with an undercut thread.

5.6.5 Bearings

Structural bearings shall conform to the requirements of EN 1337-3, EN 1337-4, EN 1337-5, EN 1337-6 or EN 1337-8 as relevant.

5.7 Adhesive bonding

Requirements for material characteristics for short and long term behaviour need to be specified in each case.

NOTE There are no European Standards giving requirements to properties of adhesives to be used for structural bonded connections.

6 Preparation

6.1 General

This clause specifies the requirements for the preparation part of the execution of aluminium structures.

Structural aluminium components shall be manufactured within the tolerances specified in 11.2.

NOTE Welding and mechanical fastening are dealt within Clauses 7 and 8.

Requirements for inspection, testing and corrections are given in 12.3.

6.2 Identification

For EXC2, EXC3 and EXC4, the constituent products shall be marked clearly or shall be uniquely identifiable (e.g. different extruded sections) if products from different alloys or the same alloy but of different tempers are used. Marking shall be by a permanent method such as paint, sticker, tag, bar code, etc. Manufacturer and constructor shall agree about the method of marking.

It shall be assured that marking does not harm the final usage of the product. Marking by chisels and by overlay welding is not allowed. Hard stamping shall not be used, unless permitted by the specification.

During each step of the manufacturing for EXC2, EXC3 and EXC4 any part or batch of similar parts of the aluminium structure shall be clearly and permanently marked or shall be otherwise uniquely identifiable, until erection.

6.3 Handling, storage and transportation

Constituent products and components shall be packed, handled, transported and stored in a safe manner, so that permanent deformation does not occur and surface damage is minimized. Any instructions from the relevant manufacturer shall be conformed to.

Constituent products that have deteriorated such that they no longer conform to the relevant standards shall be treated as a nonconformity.

6.4 Cutting

Cutting shall be carried out in such a way that the requirements to the quality of cut surface as stated in this European Standard are met.

Cutting shall be carried out by sawing, shearing, punching, thermal cutting or water jet cutting. Unacceptable tolerances or surface roughness shall be corrected by a suitable mechanical method, e.g. milling, grinding, filing or scraping.

The surface of the cuts shall be within the limits of Range 4 given in EN ISO 9013:2002, unless otherwise specified. This shall apply to perpendicularity, angular tolerance and mean height of the profile.

Sheared cuts and punched holes shall be free of cracks and notches. If not, the cut edges shall be dressed to remove all cracks and notches.

If sharp edges shall be removed due to technical reasons, it shall be specified.

Products of the alloy EN AW-7020 shall only be sheared or punched if the following subsequent operations are carried out:

- a) if welded, the sheared or punched edges shall be fully fused on their whole length. If the edges will not be fully fused by the welding, the edge shall be removed by the amount equal to 0,4 times the thickness or 3 mm, whichever is less, prior to welding;

- b) if unwelded and not machined as defined above, an additional artificial ageing may be carried out. This is only permitted for wall thicknesses up to 5 mm.

NOTE For execution of artificial ageing of EN AW-7020, see 7.7.

6.5 Forming

Forming should preferably be carried out by cold-forming processes, e.g. bending, folding or pressing to the required shape. Operations that significantly affect the material properties (e.g. softening by the application of heat, or hardening as a result of strain during the forming operation) shall only be carried out if permitted and tested as specified.

Forming shall be carried out such that cracks do not occur.

The deformed zones shall be checked according to 12.3.1 immediately following the forming process.

Marking of the bend line shall only be done using a soft pencil or felt-tip pen.

6.6 Holing for fasteners

Holes shall be formed by drilling, punching, water jet cutting or mechanized thermal cutting. Hole sizes shall be specified. The maximum clearance shall be according to Table 6. The internal surface of the holes produced by thermal or water cutting shall be within the limits of Range 4 given in EN ISO 9013:2002, unless otherwise specified. This shall apply to perpendicularity, angular tolerance and mean height of the profile. Burrs shall be removed.

For all connection categories punching shall only be permitted up to a maximum thickness of 25 mm. Punched holes in parts under tensile loads with a thickness between 16 mm and 25 mm shall be punched at least 2 mm undersize in diameter, followed by reaming.

Products of the alloy EN AW-7020 may be punched only if the requirements according to 6.4 are followed. If holes are tightly closed by bolts, the finishing work according to 6.4 is not necessary.

Where holes for bolts and rivets are drilled in parts assembled and tightly clamped together, these parts shall be subsequently separated to remove burrs, if specified.

Coolants or lubricants shall be neutral.

Maximum clearance for fasteners assemblies is given in Table 6.

Table 6 — Maximum clearances for fastener and pin holes

Fastener type and category of connection	Fastener material	Nominal fastener diameter mm	Maximum clearance on diameter ^a mm
Fitted bolts (A, D, E)	-	Any	≤ 0,3
Non-fitted bolts and pins (A, B, D, E)	-	Any	≤ 1
Fasteners in oversized holes (A, D, E)	-	Any	Greater of: 2 and 0,15 x diameter.
Solid rivets (A), see 5.6.3	Aluminium	< 13 ≥ 13	≤ 0,4 ≤ 0,8
	Steel and stainless steels	< 13 ≥ 13	≤ 0,8 ≤ 1,6
High strength bolts according to EN 14399-3, or -4 (all plies, or outer two plies if greater than three plies) (C)	Steel	≤ 24 > 24	≤ 2 ≤ 3
High strength bolts according to EN 14399-3, or -4 (above three plies, inner plies) (C)	Steel	Any	≤ 3
^a The clearance should not be increased on account of irregular or excess zinc coatings on the bolts.			

Holes for fitted bolts are drilled at least 2 mm smaller than the diameter of the thread or shaft respectively and reamed subsequently. Where the fastener is to fit through multiple plies the components shall be held firmly together during reaming.

Holes generally can also be drilled without reaming after fixing the components, if the maximum clearance is met.

Nominal dimensions of the countersinking shall be specified, which shall be such that after installation the bolt shall be flush with the outer face of the outer ply.

The angle of countersinking shall correspond to the angle of the countersunk head.

In the case of a countersunk rivet, the countersinking shall be such that after riveting the head of the rivet will fill the countersinking completely and the outer face of the ply shall be flush. The dimensions of the countersinking shall be specified.

NOTE In case of holing for self-drilling and self-tapping screws, see 5.6.4.

The effective length of slotted holes shall be specified with a deviation of +/- 1 mm for a bolt diameter < 20 mm and +/- 2 mm for bolt diameter ≥ 20 mm. The width shall not exceed (d + 1) mm (see EN 1999-1-1). The maximum values of 1,5 (d + 1) mm for short slotted holes or 2,5 (d + 1) mm for long slotted holes shall not be exceeded. Slotted holes shall exist only in one component that shall be joined.

6.7 Cut outs

Re-entrant angles and notches shall be rounded off with a minimum radius of 5 mm unless otherwise specified.

At punched cut outs in alloy EN AW-7020, the requirements in 6.6 and 6.4 apply.

6.8 Full contact bearing surfaces

The contact surfaces shall be prepared so that the requirements in 11.2.2.3 are satisfied.

6.9 Assemblies

Assembly checks shall be carried out to ensure the fitting between components. If a complete assembly check is required, it shall be specified.

The assembly checks shall be carried out in a way that the required dimensions and geometry of the components and the type and the size of any welds can be achieved as specified.

6.10 Heat treatment

Any heat treatment of constituent aluminium material shall follow a qualified procedure. Such qualified procedure can be part of the specification of the manufacturer of the constituent product. It shall only be executed if appropriate equipment is used.

6.11 Straightening

Corrections of distortion by warm straightening are not allowed with the following exceptions:

- a) if strain-hardening alloys in temper O are used;
- b) if other alloys and/or tempers are used and the straightening operations (by flame or straightening welds) are performed in low stressed zones under strict temperature control to be recorded.

The requirements to such operations shall be given in the execution specification.

NOTE Heat (temperature and duration) may influence strength and sometimes also the internal metal structure, depending on alloy and temper.

7 Welding

7.1 General

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

NOTE 1 Guidance on implementing EN ISO 3834 for quality requirements for fusion welding of metallic materials is given in CEN ISO/TR 3834-6.

With respect to execution classes, the following applies:

- 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".

NOTE 2 For welds on the surface of sheets or plates, see Note 1 in 5.3.

7.2 Welding plan

7.2.1 Requirement for a welding plan

For EXC2, EXC3 and EXC4 a welding plan shall be drawn up in accordance with the requirements of EN ISO 3834-2 or EN ISO 3834-3, as applicable.

7.2.2 Content of a welding plan

The welding plan shall at least include the following items, as relevant:

- a) connection details;
- b) weld size and type;
- c) joint preparation including removal of oxide layer;
- d) welding procedure specifications including welding consumable requirements and any pre-heating and interpass requirements;
- e) measures to take to avoid distortion during and after welding;
- f) 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 If welding 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 the masking components are assembled.

- g) any requirements for intermediate checking;
- h) any turning of components in the welding process, in connection with the sequence of welding;
- i) details of any restraints to be applied;
- j) any heat treatment specifications;
- k) any special equipment for welding consumables (storage and handling, etc.);
- l) cross reference to 12.4 of the inspection plan;
- m) requirements for acceptance criteria for welds in accordance with 12.4.4;
- n) any requirements for weld identification.

7.3 Welding process

Welding may be performed by the following welding processes defined in EN ISO 4063, unless otherwise specified:

- a) 131: metal inert gas welding, MIG-welding;
- b) 141: tungsten inert gas welding, TIG-welding;
- c) 15: plasma arc welding;

d) 43 friction stir welding (FSW).

If no welding process is specified, the MIG welding process shall be used.

7.4 Qualification of welding procedures and welding personnel

7.4.1 Qualification of welding procedures

For EXC2, EXC3 and EXC4, the welding shall be carried out with welding procedure specifications in accordance with EN ISO 15609-1. Welding procedures for FSW shall be in accordance with EN ISO 25239-4.

For EXC3 and EXC4, qualification of arc welding procedures shall be performed in accordance with EN ISO 15613 or EN ISO 15614-2 as applicable. For EXC2, qualification of welding procedures shall be performed in accordance with one of the following standards: EN ISO 15612, EN ISO 15613, EN ISO 15614-2.

For other welding processes EN ISO 15613 and the relevant part of EN ISO 15614 shall apply, as applicable.

Where EN ISO 15613 or EN ISO 15614-2 qualification procedures are used, the following conditions shall apply:

- a) butt welds tests shall not qualify fillet welds;
- b) for fillet weld qualification the procedure test in Annex C shall be included.

Welding procedure specifications for joints in hollow section lattice structures shall define the start and stop zones, and the method to be used in order to cope with the situation where the welds change from a fillet to a butt around the joint.

Where forged pieces are to be welded, depending on the shape of the forged piece, it may be necessary to prove the mechanical-technological values of the weld by a pre-production test.

Cast parts shall not be welded, unless particularly specified.

A guide for development and use of a welding procedure specification is given in Annex M.

Acceptance criteria for tensile test for FSW of non heat-treatable alloys shall be in accordance with EN ISO 25239-4. For heat treatable alloys, the following acceptance criteria apply :

$$\sigma_{\min,w} \geq f_{u,haz} \text{ and } R_{p0,2,100} \geq f_{o,haz} \quad (7.1)$$

where

$\sigma_{\min,w}$ is the tensile strength of the welded material in accordance with EN ISO 4136

$R_{p0,2,100}$ is the 0,2-proof strength in accordance with EN ISO 4136 with reference length of $L_0 = 100$ mm.

$f_{u,haz}$ and $f_{o,haz}$ are given in EN 1999-1-1.

7.4.2 Validity of the welding procedure qualification

If any welding procedure qualified in accordance with EN ISO 15614-2 has not been used by the constructor for some time, the following tests shall be carried out:

- a) if a welding procedure has not been used for more than 1 year, a production welding test, where shape and dimensions are according to the requirements of EN ISO 15614-2 and Annex C of this European Standard, if applicable, shall be carried out by the constructor. Examination and testing shall include visual inspection, radiographic inspection, surface crack detection and macro-examination;
- b) if any welding procedure has not been used by the constructor for a period of 3 years, a new welding procedure test shall be carried out by the constructor.

7.4.3 Qualification of welders and welding operators

Welders shall be qualified in accordance with EN ISO 9606-2 and welding operators shall be qualified in accordance with EN ISO 14732. The operators for FSW shall be qualified in accordance with EN ISO 25239-3.

For welding hollow section lattice structures, welders shall also be qualified by a single-side welding test carried out on a branch connection, according to Figure 1.

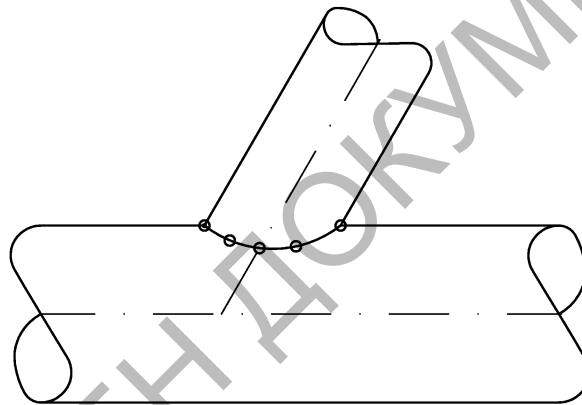


Figure 1 — Branch connection

NOTE In branch connections the weld may change between butts and fillets around the perimeter.

Certificates of all welder and welding operator qualification tests shall be retained for inspection.

7.4.4 Welding coordination personnel

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

The required technical knowledge of welding coordination personnel for EXC2, EXC3 and EXC4 is given in Table 7.

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

Table 7 — Required technical knowledge of welding coordination personnel

Execution class	Parent material	Type of welding consumables			
		Type 3, Type 4		Type 5	
		Nominal thickness of material in mm		Nominal thickness of material in mm	
		t ≤ 12 ^a	t > 12	t ≤ 12 ^a	t > 12
EXC2	3xxx, 5xxx	B	S	B	S
	Other			S	
EXC3	3xxx, 5xxx	S	S	S	C
	Other		C	C	
EXC4	all	C			
B Basic technical knowledge according to EN ISO 14731;					
S Specific technical knowledge according to EN ISO 14731;					
C Comprehensive technical knowledge according to EN ISO 14731.					
NOTE This table gives no recommendation about possible combinations of constituent materials (parent materials and filler metal) to be welded. For allowed and recommended combinations, see EN 1999-1-1.					
^a Endplates up to 25 mm.					

7.5 Preparation and execution of welding

7.5.1 General

Welding shall be carried out in accordance with the recommendations given in EN 1011-1 and EN 1011-4.

If other welding processes than stated in 7.3 are used, the requirements for welding shall be specified and be qualified by an appropriate welding procedure test.

The time interval between cleaning and welding shall be as short as possible and shall not exceed 4 h.

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

7.5.2 Joint preparation

The recommendations given in EN 1011-1 and EN 1011-4 shall apply. In addition, the following requirements apply:

- the joint preparation including tolerances and fit-up shall conform to the preparation of the welding procedure test;
- if errors in the joint geometry shall be corrected by overlay welding a qualified welding procedure shall be used. It shall be demonstrated that the property of the structure is not harmed.

7.5.3 Weather protection

Both the welder/operator and the working area shall be adequately protected against weather effects, especially wind.

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

If temperatures of material to be welded are below 5 °C, suitable heating can be necessary.

7.5.4 Assembly for welding

The recommendations given in EN 1011-1 and EN 1011-4 shall apply. In addition, the following requirements apply:

- a) components to be welded shall be brought into alignment and held by tack welds or external devices and the alignment shall be maintained during initial welding;
- b) assembly shall be carried out such that the fit-up of joints and the final dimensions of the components are within the specified tolerances, suitable allowance shall be made for distortion and shrinkage;
- c) 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/operator/inspector.

7.5.5 Temporary attachments

It shall be specified if welding of temporary attachments is permitted. If permitted, the locations where this welding is not allowed shall be specified.

The recommendations given in EN 1011-1 and EN 1011-4 shall apply. In addition, the following requirements apply:

- a) all welds for temporary attachments shall be made in accordance with the welding procedure specification;
- b) if temporary attachments have to be removed by cutting or chipping, the surface of the parent metal is subsequently to be carefully ground smooth and flush;

7.5.6 Tack welds

The recommendations given in EN 1011-1 and EN 1011-4 shall apply. In addition, the following requirements apply:

- a) tack welds shall be located in positions suitable for the start/stop position;
- b) for joints welded by an automatic or fully mechanized welding process for EXC3 and EXC4 the conditions for deposition of tack welds shall be included in the welding procedure specification.

7.5.7 Preheating and interpass temperature

Preheating and interpass maximum temperature shall be as recommended in EN 1011-4.

7.5.8 Butt welds

The recommendations given in EN 1011-1 and EN 1011-4 shall apply. In addition, the following requirements apply:

- a) the location of butt welds used as splices to accommodate available lengths of constituent products shall be specified;
- b) for EXC3 and EXC4, and for EXC2 if specified, run-on/run-off pieces shall be used to ensure full throat thickness at the edge;

- c) after completion of the welds any run-on/run-off pieces or supplementary material shall be removed and their removal shall conform to 7.5.5.

7.5.9 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.

The first pass shall complete the circumference of the hole.

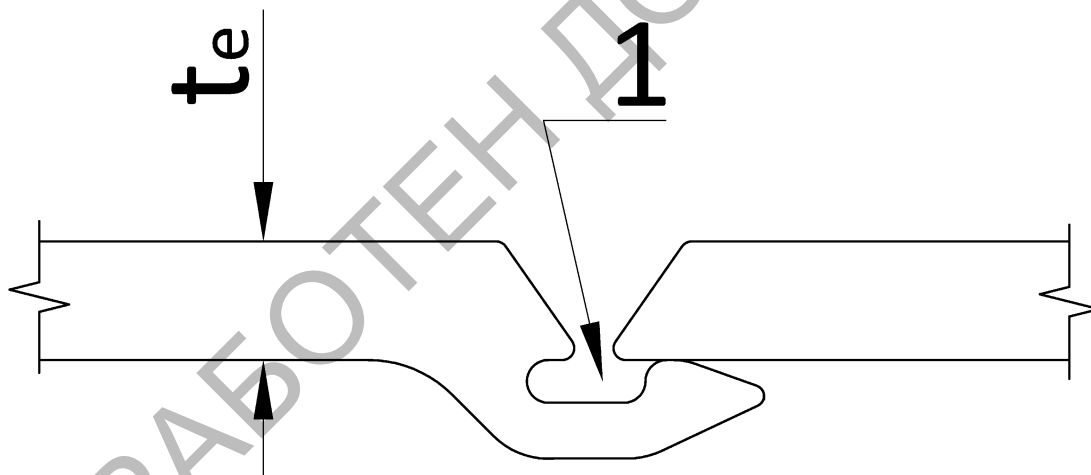
Plug welds shall be made only after the fillet welding in the slot has been checked as satisfactory. Plug welds performed without previous slot welding are not permitted unless otherwise specified.

7.5.10 Fillet welds

If specified, fillet welds finishing at the ends or sides of parts should be returned continuously, full size, around the corner for a distance of at least twice the leg length of the weld.

7.5.11 Single sided welds

Full penetration welds welded from one side should have backing. If backing is not used, a special WPS shall be followed, adapted to the given structural situation. The backing shall have a space for contamination in the bottom of the joint and outside the required penetration. The size and form of the backing shall be included in the WPS. The backing shall be continuous and may be a part of an extrusion. See Figure 2 for an example.



Key

- 1 space for contamination

Figure 2 — Example of extruded backing for single sided weld with penetration depth, t_e , where the shape of the space for contamination is dependent of the thickness of the welded part

For partly penetrated welds, the size and form of the joint shall be included in the WPS. The penetration depth shall be specified. Welding in accordance with the WPS shall give consistent penetration depth.

7.5.12 Friction stir welding

For friction stir welding, FSW, the inspection and testing before and during welding shall be in accordance with EN ISO 25239-5. The lay-out of the FSW joints shall be in accordance with EN ISO 25239-2.

7.5.13 Other welds

The requirements for other welds made by other processes than stated in 7.3 shall be specified and shall be subject to the same welding requirements as specified in this European Standard.

For weld studs connected by arc stud welding with tip ignition, see Annex N.

7.6 Acceptance criteria

The acceptance criteria are given in 12.4.4 and 12.4.5.

7.7 Post-weld heat treatment

If a complete heat treatment (solution treatment, quenching and ageing) or an artificial ageing of welded components is required, a qualified procedure shall be used. The influence of the heat treatment on strength shall be proved by a procedure test according to EN ISO 15614-2. This is also required if repair welding needs a post-welding treatment, except for the alloy EN AW-7020 where recommendations are given in Note 3.

The procedure test has to prove that the chosen method meets the requirements for the strength, stability of shape and dimensional accuracy. Further agreed quality requirements have to be considered as well, e.g. anodic oxidation treatment.

NOTE 1 Guidance on post-weld heat treatment can be obtained from EN ISO 17663. Further specific guidance can be obtained from the manufacturer of the constituent product.

NOTE 2 A heat treatment in the form of artificial ageing has practically no influence on shape and dimensional accuracy of the structure.

NOTE 3 For artificial ageing of products of the alloy EN AW-7020 and the post welding artificial ageing of welded components of this alloy, the following temperature steps have been shown to be appropriate:

- 1st step > 3 days at room temperature;
- 2nd step 8 h to 10 h at + 90 °C ± 5 °C (metal temperature);
- 3rd step 14 h to 16 h at + 145 °C ± 5 °C (metal temperature).

In case of repairing structures of EN AW-7020 by welding the weld repair area may be heat treated using heating blankets. The following temperature treatment has been shown to be appropriate:

- 22 h to 26 h at + 120 °C ± 5 °C (metal temperature).

Welded products of the alloy EN AW-7020 that have not been the subject of a post welding heat treatment shall not be subjected to full load before a natural ageing period of 30 days. The natural ageing period may be shortened if a special treatment is carried out according to the procedure specification.

NOTE 4 The following heat treatment has been shown to be appropriate:

- 60 h at + 60 °C ± 5 °C (metal temperature).

Documentation of the heat treatment history is required.

8 Mechanical fastening and adhesive bonding

8.1 Joint assembly for mechanical fastening

8.1.1 Preparation of contact surfaces

At the time of assembly, the contact surfaces (coated or uncoated) shall be free from all contaminants. Contact surfaces shall be smooth and without burrs to enable a solid seating of the parts to be connected.

Oil shall be removed from the surface by using chemical cleaners, not by flame cleaning.

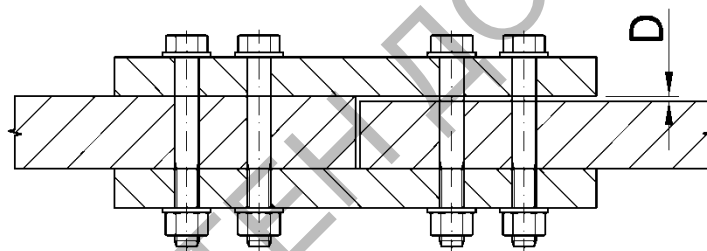
If sealing of contact surfaces is required, Clause 10 applies.

8.1.2 Fit-up

Separate components forming part of a common ply shall not differ in thickness by more than D , where D is 1 mm generally or 0,5 mm in preloaded applications (see Figure 2). If shims are provided to ensure that the difference in thickness does not exceed the above limit, their thickness shall not be less than 1 mm.

NOTE 1 In case of severe corrosive exposure, avoiding crevice corrosion may require sealing of the gap.

NOTE 2 It is advised that thickness be fitted so as to limit the number of shims to a maximum of three.



Key

D difference

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

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

NOTE It is not necessary to secure additionally preloaded connections against loosening if the bolts are preloaded according to 8.3.2.

The proper assembly and alignment shall be assured before mounting bolts for preloaded connections (if necessary mandrels or temporary bolts shall be used).

8.1.3 Preparations of contact surfaces in slip-resistant connections

The extent of contact surfaces in slip-resistance connections shall be specified.

Unless otherwise specified, the contact surfaces shall be lightly grit blasted to a roughness value, $R_a = 12,5$ measured in accordance with EN ISO 4288.

For other surface treatments, the slip factor may be determined using the procedure given in Annex D. If the measured slip factor does not conform to the specified slip factor, adequate corrective actions shall be taken.

All necessary precautions shall be taken during manufacturing and erection to ensure that the required property of the friction surface is achieved and kept.

8.2 Bolted connections

8.2.1 General

The combination of bolt, nut and washer shall be in accordance with Table 5.

In preloaded bolts and bolts with tension the thread of the bolt shall protrude at least one thread over the nut. For bolt category A, it is sufficient if the thread ends even with the nut.

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

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

For preloaded bolts according to EN 14399-4 and EN 14399-8, clamp lengths shall be in accordance with those specified in EN 14399-4.

For slotted holes the thread shall not go into the joined components, if the slotted holes are planned to absorb thermal expansion. If bolt heads or nuts are directly in contact with components with slotted holes it is necessary to use over-sized washers or plates to cover the holes totally.

8.2.2 Bolts

Bolts shall not be welded, unless specified.

Bolts shall be inserted without damaging the threads.

Using bolts in components with inside thread it is necessary to have a special adaptation with the manufacturer of the constituent product regarding the fitting of the thread and tightening of the bolts.

8.2.3 Fitted bolts

Fitted bolts might be used in preloaded and non-preloaded applications.

The thread of a fitted bolt shall not be included in the shear plane. The length of the threaded portion of the shank of the fitted bolt included in the bearing length shall not exceed $1/3$ of the thickness of the plate unless otherwise specified, see Figure 3.

NOTE The thread run out belongs to the threaded portion of the bolt.

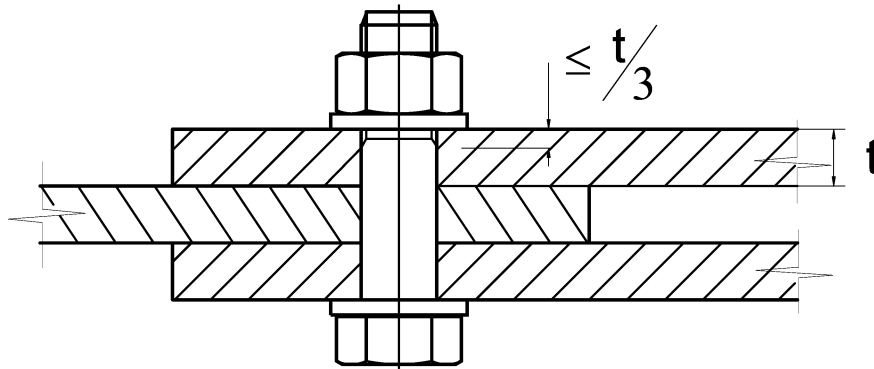


Figure 4 — Maximum threaded portion of the shank in the bearing length for fitted bolts

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

8.2.4 Countersunk bolts

Countersunk bolts may be used in connections where the nominal thickness of the outer ply is 1,5 mm greater than the depth of the countersunk head.

8.2.5 Nuts

For EXC1, EXC2 and EXC3 locking devices are not required, unless specified. The nuts of non-preloaded bolts for EXC4 shall generally be secured.

NOTE 1 Securing the nut can be done by locking devices e.g. lock nut, counternut, pasting material, etc. or by other means.

Nuts shall run freely by hand on their partner bolt. If a tool is necessary for entering one of the nuts, one nut shall be checked for free running by hand after initial loosening and prior to tightening for every new batch of nuts and bolts.

NOTE 2 For some types of locking devices the nuts will not run free by hand.

The threads of aluminium and stainless steel bolts shall be lubricated before assembly if the joint will subsequently be dismantled.

For EXC3 and EXC4, nuts shall be assembled so that their designation markings are visible for inspection after assembly.

NOTE 3 For washer faced nuts this would generally ensure that the washer face of the nut is correctly positioned although this is not essential for the bolt to act in bearing.

Using nuts with bars having outside thread it is necessary to have a special adaptation with the manufacturer of the constituent product regarding the fitting of the thread and tightening of the nut.

8.2.6 Washers

Washers shall be used under the bolt head and the nut. Preloaded bolt assembly system HR shall have chamfer washers (EN 14399-6) under the bolt head and chamfer washers (EN 14399-6) or plain washers (EN 14399-5) under the nut. Preloaded bolt assembly system HV shall have chamfer washers (EN 14399-6) under the bolt head and the nut. The chamfer shall be towards the bolt head and the nut.

Plate washers shall not be thinner than 4 mm.

Up to two washers may be used under the nut.

It shall be specified whether normal (EN ISO 7089) or over-sized washers (EN ISO 7093, EN ISO 7094) shall be used.

The bearing surface at the component shall not be at a greater inclination than 2 % to the bearing surface at the bolt head and the nut.

8.3 Tightening of bolted connections

8.3.1 Non-preloaded connections

The components to be connected shall be drawn together so that they achieve firm and tight contact. Shims may be used to adjust the fit-up, see 8.1.2.

During this process each bolt assembly shall be brought at least to a snug-tight condition without overloading the bolts or the contact area under the bolt heads or the nuts. In large bolt groups this process shall be carried out progressively from the middle of the group to the outside. To achieve uniform snug-tight conditions, more than one cycle of tightening can be necessary. Sufficient precautions shall be taken so as not to overtighten short bolts, M12 bolts or smaller.

Locking devices shall be used as specified.

Only neutral lubricants shall be used. Neutral lubricants are lubricants with a pH-value between 4,5 and 8,5. Grafite based lubricants shall not be used.

NOTE 1 The term “snug-tight” can generally be identified as that achievable by effort of one person using a normal sized spanner without any extension arm, and can be set as the point at which a percussion wrench starts hammering.

NOTE 2 Overloading the area under the bolt heads and nuts may cause creep and a reduction in the tightening of the bolts.

8.3.2 Preloaded connections

Before commencement of preloading, the connected components shall be fitted together and the bolts in a bolt group shall be tightened in accordance with 8.3.1 where the residual gap is limited to 0,5 mm.

Tightening shall be performed by rotation of the nut unless the access to the nut side of the assembly is prevented by the orientation of the bolt.

Tightening sequence 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 can be necessary.

NOTE 1 The most rigid part is commonly in the middle of the bolt group.

For slip-resistant connections, the bolts shall be tightened so as to achieve the required long term preloading force. Effects of relaxation, creep and settlement shall be taken into account, i.e. all joints shall be tightened once more after a period of 72 h, unless otherwise specified.

Unless otherwise specified, the preload shall be taken as:

$$F_{p,C} = 0,7x f_{ub} x A_S$$

where

$F_{p,C}$ is the preloading force;

f_{ub} is the characteristic ultimate strength of bolt material;

A_S is the tensile stress area of a bolt;

as defined in EN 1999-1-1.

Table 8 gives values of the preload.

Table 8 — Values of preloading force in kN

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

NOTE 2 If the preload is not explicitly used in the design calculations for slip resistance but required for execution purposes or as a quality measure, a lower preload can be specified.

For slip-resistant connections, tightening shall be carried out by the torque method in accordance with EN 1090-2. For other pre-loaded connections, tightening by the torque method, the combined method, or direct tension indicator method, in accordance with EN 1090-2, can be carried out if specified.

The direct tension indicator method shall only be applied in dry areas.

Torque wrenches used shall be capable of an accuracy of $\pm 4\%$ according to EN ISO 6789. Each wrench shall be checked for accuracy at least once per working day, and in case of pneumatic wrenches, every time the hose length is changed. Checking shall be carried out after any incident occurring during use (significant impact, fall, overloading, etc.).

High strength bolts for preloading shall generally be used without alteration of the as-delivered lubrication. If additional lubricant is used, the suitability of bolt assembly for preloading shall be checked in accordance with EN 14399-2.

Where a bolt assembly that has been tightened to the minimum preload is later untightened, it shall be removed and the assembly shall be replaced.

Bolt assemblies not preloaded to the required preload for slip-resistant connections can be reused.

The tightening method shall be calibrated in accordance with EN 1090-2.

8.4 Riveting

8.4.1 General

The requirements of 8.1.1 and 8.1.2 shall apply.

Rivets shall be driven cold.

Rivets shall be of sufficient length to provide a head of uniform and specified dimensions.

8.4.2 Installation of rivets

Rivets shall be driven so as to completely fill the holes. Heads shall be concentric with their shanks and in close contact with the riveted surfaces. Tubular and other special rivets shall be formed using the tools and procedure recommended by the manufacturer of those. Loose or defective rivets shall be removed, preferably by drilling or machining away the head and punching the shank through.

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

For multiple riveted connections, a temporary bolt shall be tightened in at least every fourth hole prior to driving or alternative means of ensuring that the joint is maintained in the correct alignment shall be used.

Special measures shall be taken to hold components of single riveted connections together.

NOTE Wherever practicable, riveting will preferably be carried out using machines of steady pressure type. The driving pressure will preferably be maintained on the rivets for a short time after upsetting is complete.

8.5 Adhesive bonded connections

The method of making bonded joints shall be specified and it shall be documented that the process is repeatable.

The requirements for inspection of the adhesive bonding process, the extent of testing and the acceptance criteria shall be specified.

9 Erection

9.1 General

If welding is executed on site or outside of the workshop, then protection, access and working arrangements shall be provided to give a dry, draught free environment comparable to workshop conditions.

Preparation, welding, mechanical fastening and adhesive bonding and surface treatment undertaken on site shall conform to Clauses 6, 7, 8 and 10 respectively.

9.2 Site conditions

Recommendations for the description of site conditions are given in Annex J.

9.3 Erection method statement

An erection method statement shall be prepared and checked to ensure that the method conforms to the design assumptions, notably with regard to resistance of the partly erected structure to loads applied during construction.

NOTE The erection method statement may deviate from the design basis method of erection, provided that it is a safe alternative.

Guidance for items to be considered in the erection method statement is given in Annex J.

9.4 Supports

All foundations and other supports shall be suitably prepared to receive the structure.

Erection shall not commence until the supports have been demonstrated to comply with the requirements.

The checking of the support locations shall be documented in a surveying inspection report.

The installation of bearings shall be in accordance with EN 1337-11.

9.5 Execution on site

9.5.1 Site survey

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 aluminium structure 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 aluminium structure shall be specified.

9.5.2 Marking

Components shall have a clear marking for assembly and erection.

A component shall be marked with its erected orientation if this is not clear from its shape.

9.5.3 Handling and storage at site

Components shall be handled and stacked in such way that the likelihood of damage is minimized.

Fasteners stored on site shall be kept in dry conditions and shall be suitably packed and marked.

All small plates and other fittings shall be suitably packed and marked.

9.5.4 Erection methods

The erection of the structure shall be carried out in conformity with the erection procedures and in such a way as to ensure stability of the aluminium structure and any temporary members at all times.

All connections for temporary members provided for erection purposes shall be as specified and in such a way that they do not weaken the permanent structure or impair its serviceability.

If the erection procedures involve moving the structure, or part of the structure, into its final position after assembly, provisions shall be made to avoid uncontrolled movements of the moveable part. Correct designed bumpers and guides may be used to control and secure the movement.

All temporary anchoring devices shall be able to safely carry the foreseen forces.

9.5.5 Alignment and grouting

Shims and other parts used as packing under the bearing plate shall be plane and of suitable size, stability and hardness. A local failure of the foundation shall be avoided.

If shims are left in their place after grouting, they shall be from a material that has at least the same durability as the structure and shall not cause any corrosion.

The shims shall be made of aluminium and may be plane sheets. For outside applications a minimum thickness of the shims of 1 mm is required.

Alignment of the structure and lack of fit in connections may be adjusted by the use of shims. Shims shall be secured if it is any possibility that they can become loose.

Correction of misalignment may be made by reaming of holes or milling of contact surfaces. In all cases the requirements of Clause 6 shall be followed.

If shims are grouted afterwards, it is necessary to arrange them in such a way that there is a minimum grout cover of 25 mm to all sides, if not otherwise specified. Grouts aggressive to aluminium and hygroscopic grouts shall not be used (see 10.3.4).

The grouting shall be carried out in accordance to the specification for the work.

9.6 Protection of surfaces, cleaning after erection

Cleaning procedures shall be appropriate for the alloy, surface finish, function of the component and take into account the risk of corrosion.

Contact between aluminium material and strong acid or base shall be avoided. If such contamination does happen, the solution shall be washed off immediately with sufficient amounts of water.

10 Surface treatment

10.1 General

Structures made of aluminium alloys listed in EN 1999-1-1 do not need protective treatment during service under normal atmospheric conditions. Nevertheless, appropriate measures shall be taken that no corrosion or contamination occurs during execution.

If components have to be stored outdoors, all parts should be well ventilated and drained.

NOTE Protecting components and semi-products stored outdoors by direct covering with canvas or similar covering material cannot generally be recommended, since depending on different circumstances the appearance of the surface may be influenced negatively.

Each protective treatment shall be expressly required and specified.

Fire protection systems shall be in accordance with the required fire class.

10.2 Protection of the structure and components

Coating, anodizing and passivation may be performed according to Annex E, unless otherwise specified.

The inner surface of hollow sections shall only get a protective treatment if expressly specified.

10.3 Protection of contact surfaces and fasteners

10.3.1 General

The nature and extent of all protection measures shall be specified.

Special treatments of contact areas should prevent or minimize contact corrosion (galvanic corrosion) and crevice corrosion. Crevice corrosion is possible in each kind of crevice e.g. also between plastic and aluminium.

10.3.2 Contact surfaces aluminium-to-aluminium and aluminium-to-plastics

If a simple sealing of contact surfaces is specified, the parts shall be cleaned and the sealing shall be done with a suitable sealing compound or coating. The consistency of the sealing compound shall ensure that all crevices are and remain closed. The parts should be jointed before the coating or the sealing compound is completely dried.

If a protection of the contact surface is specified for structures in a severe industrial or marine environment or for structures immersed in water, both contact surfaces shall be assembled so that no crevices exist where water can penetrate. Both contact surfaces, including bolt and rivet holes shall, before assembly, be cleaned, pre-treated and receive one priming coat (see F.2), or sealing compound, extending beyond the contact area. The surfaces should be brought together while the priming coat is still wet. Assemblies of pre-painted or otherwise protected components shall be sealed as specified.

10.3.3 Contact surfaces of aluminium and steel or wood

If protection measures are specified on the aluminium surface in cases of contact between aluminium components with parts made of steel, the aluminium surfaces shall be treated according to F.2.

For contact with wood a coating is not required, unless the wood has been treated with an aluminium harming product (e.g. copper sulphate). In such cases a coating protection is necessary, which unless otherwise specified shall be carried out according to F.2.

NOTE It is assumed that the execution specification gives information on the chemical composition of the treatment product used for the wood in contact with the aluminium structure and any requirements for a coating protection.

The contact surfaces of steel components shall be coated with a material that contains no aluminium attacking components.

Where full electrical insulation is specified between the two metals and all fixings, it shall be ensured by insertion of non-absorbent, non-conducting tapes, gaskets and washers to prevent metallic and electrical contact between the different metals of the joint. Care shall be taken to ensure that there are no crevices between the insulation materials and the metal. The use of additional coating or sealants may be necessary.

10.3.4 Contact surfaces of aluminium and concrete, brickwork and plaster, etc.

If protection measures are specified on the aluminium surface in cases of direct or indirect contact between aluminium components with concrete, brickwork or plaster, before assembly the aluminium surface shall be covered with a bitumen layer or another suitable coating with a thickness of at least 100 µm, if not otherwise specified.

NOTE An aggressive reaction between concrete and aluminium only takes place if moisture is present. Therefore, for secondary parts a coating may not be necessary. Coatings become necessary even if there is no direct contact between aluminium and concrete if water runs from concrete over to aluminium surfaces. There are flash set binders and other admixtures for concrete that are hygroscopic and especially aggressive. If the use cannot be avoided in this case, a very careful tight coating needs to be applied.

In contact with soils the coating of the aluminium surface shall be done in two layers of bitumen or another suitable coating with a thickness of at least 100 µm.

10.3.5 Fasteners

If sealing measures for fasteners are specified, care shall be taken that all connected surfaces (also shaft) are covered by a sealing compound. The assembly of the parts should be done before the coating or the sealing compound is completely dried.

If it is necessary to protect the outside surfaces of fastener devices, an adequate surface pre-treatment shall be executed.

10.3.6 Bonded joints

The protection system specified shall be applied. The advice of the adhesive manufacturer shall be sought to ensure there is no interaction between the adhesive and the protective system, e.g. solvent or heat effects.

10.4 Fire protection

Only fire protection systems classified for aluminium structures or dry fire protection insulation shall be used.

The installation of fire protection systems shall be in accordance with the manufacturer's installation manual.

The installation of dry fire protection insulation shall be in accordance with the test classification certificate or as specified.

11 Geometrical tolerances

11.1 Types of tolerances

This clause defines two types of geometrical tolerances:

- 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.

The Annexes F, G and H give quantitative values of permitted deviations for the types a) and b).

NOTE The permitted tolerance is the difference between the upper limit of size and the lower limit of size.

Essential tolerances as well as functional tolerances are normative, however, only the essential tolerances are referred to in EN 1090-1.

If components are to form parts of a structure that is to be erected on site, any intermediate checking of components shall be subordinate to the final checking of the erected structure.

The permitted deviations given do not include elastic deformations.

The dimensions specified (on the drawings) are dimensions referring to room temperature (20 °C). If the measurements are taken at other temperatures they shall be converted to measurements at 20 °C.

In addition, special tolerances may be specified either for types of geometrical deviations already defined with quantitative values or for other types of deviations. If special tolerances are required the following information shall be given:

- i) amended permitted deviations for types of deviation tabulated in Annexes F, G and/or H;
- ii) further types of deviation to be checked, together with defined parameters and permitted values;
- iii) whether these special tolerances apply to all relevant components or only to particular components that are specified.

11.2 Essential tolerances

11.2.1 General

Essential tolerances shall be in accordance with Annex F and/or H. The requirements are for final acceptance testing.

The values specified are permitted deviations. Nonconformities shall be dealt with in accordance with 12.7.

11.2.2 Manufacturing tolerances

11.2.2.1 Incorporation of constituent or prepared products into components

After incorporation of constituent or prepared products into a component, the permitted deviations specified by the standard for these products apply, unless this European Standard gives more stringent tolerance requirements.

11.2.2.2 Manufactured components

The geometrical deviations of manufactured components shall not exceed the values given in Tables F.1 to F.9.

11.2.2.3 Surfaces finished for full contact bearing

The squareness of the contact surfaces shall be as given in Table G.2 C.

If the flatness of a single surface is checked against a straight edge, before assembly with its mating surface, the air gap between the surface and the straight edge shall not exceed 1,0 mm anywhere.

NOTE If a trial assembly of such a connection is undertaken to check this fit-up requirement, it is advised to interpret it carefully as the erection process may constrain the ability to align the components in exactly the same

way that they are during trial assembly, and the self-weight of the aluminium structure may eliminate local high spots on the surface.

If stiffeners are fitted with the purpose of transmitting forces in full contact bearing, the gap between bearing surfaces shall not exceed the requirements in G.2.3.

11.2.2.4 Oversized holes

For connections where oversized holes are used, the centre of each oversized hole of a group of holes shall be in line with the centre of the corresponding normal hole with a deviation of max. 1 mm.

11.2.2.5 Shell structures

The geometrical deviations in shell structures shall not exceed the values given Annex H. The tolerance class shall be specified. For tolerance class 4, the boundary conditions BC shall be specified in accordance with EN 1999-1-5.

11.2.3 Erection tolerances

11.2.3.1 Reference system

Deviations of erected components shall be measured relative to their position points (see ISO 4463).

If a position point is not established, deviations shall be measured relative to the secondary system.

NOTE ISO 4463-1 refers to the establishment and connection of reference system as follows:

- a) The primary system, which normally covers the whole site;
- b) The secondary system, which serves as the main reference system or grid for the erection of a particular building;
- c) 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.

11.2.3.3 Columns

11.2.3.3.1 Bases

The position in plan of the centre of an aluminium column at its base shall be set to within ± 5 mm of its position point.

Holes in base plates 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 structure. This may require the use of special large and thick washers between the nuts on the holding down bolts and the top of the base plate.

The base level of the bottom of the column shaft shall be set to within ± 5 mm of the specified level relative to its position point. This may be achieved by setting the level at the underside of the base plate, provided that compensation is made for significant thickness variation in the base plate.

11.2.3.3.2 Verticality

The deviation of erected columns shall conform to the permitted deviations in Table F.8.

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 F.8. The requirement applies to two perpendicular directions;
- b) the permitted deviation for the inclination of an individual column within this group, between adjacent storey levels may then be relaxed to $|\Delta| = h/100$.

11.2.3.3 Full contact bearing

If full contact end bearing is specified in bolted splices, the fit-up between surfaces of erected component shall be in accordance with Table F.10 after alignment and bolting-up. If the gap exceeds the specified limits, shims may be used to reduce the gaps to within the permitted deviation. The shims may be made of flat aluminium of corresponding strength or stainless steel. No more than three layers of shims shall be used at any point. If allowed by the specification, the shims may be held in place by means of welding.

11.3 Functional tolerances

11.3.1 General

Annex G contains requirements for functional tolerances for components and structures.

Reference systems and other general requirements specified in 11.2.3.1 apply.

The deviations given in Annex G are for final acceptance testing of the end product.

Nonconformities shall be dealt with in accordance with 12.7.

11.3.2 Manufacturing tolerances

11.3.2.1 Tolerances for commonly used components and structural details

Permitted values for functional tolerances for commonly used components and structural details are given in the Tables G.1 to G.8.

Table G.7 may be applied to other horizontal and sloping primary structural components at intermediate and roof level, for which deviations are measured with respect to their intended plane rather than level.

Care is needed in implementing these requirements if beams or rafters form part of unbraced frames as elastic deflections and movements may be relatively large.

11.3.2.2 Tolerances for other components and structural details

Annex G does not cover all possible situations. If none of the shown situations can be applied, the following general criteria may be used to specify the tolerances:

- a) for welded structures, apply the following classes according to EN ISO 13920:
 - class C for length and angular dimensions;
 - class C for length and angular dimensions;
- b) in other cases, apply a general tolerance to any dimension "D". This tolerance is $D/500$, but in minimum 5 mm.

11.3.2.3 Tolerances for constituent or prepared products

After incorporation of constituent or prepared products into a component, the permitted deviations specified by the standard for these products apply.

NOTE During some manufacturing processes, the geometry could be influenced such that the deviations are larger than the permitted deviations in Annex G or the relevant product standard. In such cases, it is advised to agree and specify larger functional tolerances than those given in Annex G or the relevant product standard.

12 Inspection, testing and corrections

12.1 General

This clause specifies the requirements for inspection and testing with respect to the requirements included in quality documentation as specified in 4.2.1.

Inspection, testing and corrections shall be undertaken as specified and within the requirements of this European Standard.

Inspection and testing shall be undertaken to a predetermined plan.

All inspection and testing undertaken and associated corrections shall be documented.

12.2 Constituent products and components

12.2.1 Constituent products

Documents supplied with constituent products in accordance with the requirements of Clause 5 shall be checked to verify that the information on the constituent products supplied matches those ordered.

NOTE These documents include inspection certificates, test reports, declaration of compliance as relevant for plates, sections, hollow sections, welding consumables, mechanical fasteners, studs.

The inspection of the surface of constituent products shall be included in the inspection plans if necessary from the use of the product.

There are no requirements for specific testing of constituent products unless 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 part-manufactured components received into a constructor's works for further processing, and to products received on site for erection by the constructor if these are not manufactured by the constructor.

12.3 Preparation

12.3.1 Forming

The deformed zones of shaped material (e.g. at bent sheets) shall be checked with a magnifying glass with a magnification of 10 times. The test result shall be reported.

12.3.2 Geometrical dimensions of components

The inspection plan for manufacturing shall be related to the requirements for the works and shall consider the checks necessary on the prepared constituent products, part-manufactured and fully manufactured components.

Dimensional measurements of manufactured components shall always be taken. Methods and instruments used shall be selected, as appropriate, from those listed in ISO 7976-1 and ISO 7976-2. Accuracy shall be assessed in accordance with the relevant part of ISO 17123.

The location and frequency of measurement shall be specified in the inspection plan.

The acceptance criteria shall be in accordance with 11.2 and 11.3. The deviations shall be measured with respect to any specified camber or preset.

If inspection results in the identification of nonconformity, the action on such nonconformity shall be as given in 12.8.2.

12.4 Welding

12.4.1 Inspection stages

Inspections required before, during and after welding shall be stated in the inspection plan and subject to approval as specified.

NOTE Guidance is given in the relevant part of EN ISO 3834.

If the inspection plan requires a check of the fit-up before the welding of sections prepared for branch welding, the following locations shall be given particular attention:

- for circular sections: the mid-toe, mid-heel and two mid-flank positions;
- for square or rectangular sections: the four corner positions.

The joint preparation, joint fit-up and welding access shall be inspected and approved prior to welding. Any weld becoming inaccessible by subsequent work shall be examined prior to that work being executed.

In case of distortion that exceeds the limits given in the specification, which shall be corrected by cold straightening, the welds in this region shall be re-inspected. Warm straightening is only allowed if the conditions for its use is specified, see 6.11.

If a welded structure or component is to be post-weld heat-treated the final inspection after welding shall be performed after the heat treatment.

12.4.2 Methods of inspection and personnel qualification

12.4.2.1 Methods

Visual inspection shall be carried out in accordance with EN ISO 17637.

The measuring of the throat thickness "a" shall be in accordance with EN ISO 17659 and EN ISO 17637. See also Figure 5, 6 and 7.

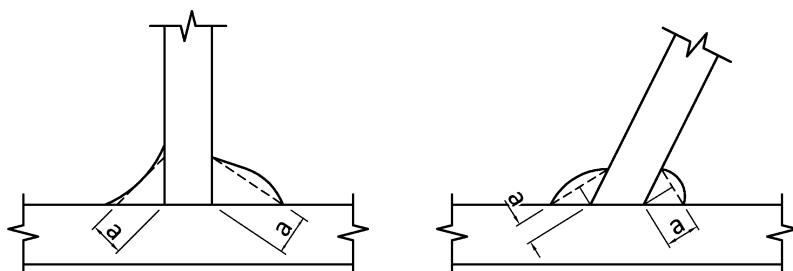


Figure 5 — Throat thickness « a » for fillet welds with unequal leg lengths

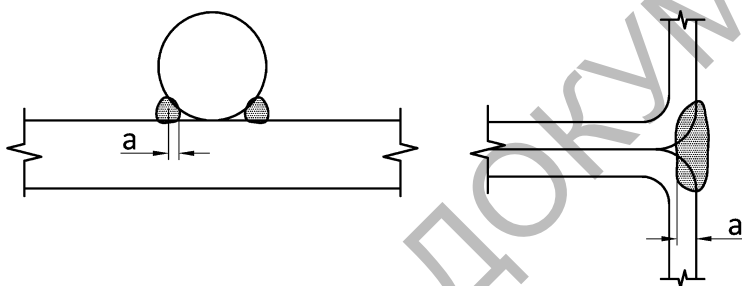


Figure 6 — Throat thickness « a » for flare groove welds

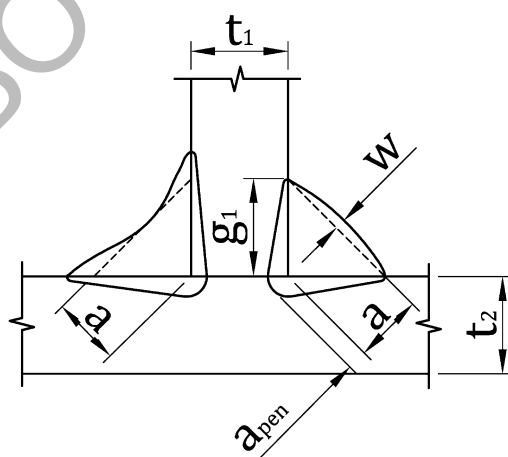


Figure 7 — Deep root penetration « a_{pen} » and « w » for convex weld

Additional NDT shall be carried out in accordance with the following standards where required by 12.4.3:

- a) penetrant testing (PT) - EN ISO 3452-1;
- b) ultrasonic testing (UT) - EN ISO 17640;
- c) radiographic testing (RT) - EN ISO 17636-1 and EN ISO 17636-2.

Destructive testing shall be carried out in accordance with EN ISO 9017 and EN ISO 17639.

The inspection of the shape and surface of welds of welded branch joints 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.

Test class B according to EN ISO 17636-1 and EN ISO 17636-2 shall be achieved when applying the radiographic inspection. If due to the thickness of the sheet or lack of accessibility gamma rays have to be used and it is not possible to achieve the requirements according to test class B, the acceptance of the purchaser for this or an alternative inspection method shall be obtained.

For an ultrasonic inspection of components under predominantly static loading (SC1), test class B according to EN ISO 17640 is required.

FSW shall be tested by bending test in accordance with EN ISO 25239-5.

12.4.2.2 Qualification of inspection personnel

Non-destructive testing (NDT) methods shall be selected in accordance with EN ISO 17635 as the basis for inspection and test plan required by the welding plan. NDT, with the exception of visual inspection, shall be performed by personnel qualified according to Level 2 as defined in EN ISO 9712.

12.4.3 Extent of inspection

12.4.3.1 General provisions

The extent of all inspection and quality requirements shall be specified. All welds or parts of welds that require inspection shall be unequivocally defined or designated. Subjects in the specification are:

- a) execution class;
- b) service category (significant fatigue SC2 or predominantly static SC1);
- c) quality level according to EN ISO 10042;
- d) additional and supplementary quality requirements e.g. according to this European Standard and EN 1999-1-3;
- e) extent of additional NDT;
- f) any additional tests and testing methods.

12.4.3.2 Provisions for welds

All welds shall be visually inspected throughout their entire length in accordance with EN ISO 17637. If surface breaking planar defects are detected, surface testing by liquid penetration testing shall be carried out on the inspected weld.

For examples of how to present these requirements on drawings, see Annex I.

The minimum extent of inspection for welded joints shall be specified as follows:

- a) Table K.2 should be used for SC1 and Table K.3 should be used for SC2;
- b) A new WPS (welding procedure specification) shall be checked under production conditions and the following requirements shall apply:
 1. For the first five joints made to the same WPS:

NOTE The check can be carried out at joints on one or more structures, regardless of the EXC.

 - i) the quality level B shall be achieved;
 - ii) the length to be inspected shall be 100 % but need not to be more than 300 mm for each joint.
 2. If inspection gives nonconforming results, investigation shall be carried out in order to find the reason and a new set of five joints shall be tested.
- c) Any additional provisions required.

For the methods of NDT and destructive testing for FSW to be applied see Table 9.

The specified values for the NDT given in per cent refer to the length of the weld or the welds and applies to each component or structure as relevant. Each WPS shall be equally represented.

Table 9 — Test methods to be applied for NDT ^{a, b, c} and destructive testing for FSW

EXC	Butt welds	Partial penetrated welds	Fillet welds	FSW
1	PT	-	-	-
2	RT or UT	PT + UT ^d	PT	Bend test ^e
3	PT + (RT or UT)	PT + UT ^d	PT	Bend test ^e
4	PT + (RT or UT)	PT + UT ^d	PT	Bend test ^e

^a Penetrant testing (PT) shall be carried out in accordance with EN ISO 3452-1.

^b Ultrasonic testing (UT) shall be carried out in accordance with EN ISO 17640, Technique 1 and Testing level B. Acceptance criteria in accordance with Table 14.

^c Radiographic testing (RT) shall be carried out in accordance with EN ISO 17636-1 (alternatively EN ISO 17636-2), class B

^d UT is applicable for penetration depth ≥ 12 mm

^e Bend test shall be in accordance with EN ISO 25239-5

12.4.3.3 Destructive testing

Destructive testing shall only be executed if specified.

12.4.3.4 Additional inspection following nonconformity in quality level

If a random inspection has been specified, the checks shall be carried out on welds where the highest tension stress occurs. The selection of the weld to be checked shall ensure that the testing covers the welding conditions as widely as possible, i.e. the joint type, the material, the welding equipment and the work of individual welders.

If as a result of a randomly performed inspection, irregularities in the welds are found which do not fulfil the criteria for the weld quality level, the extent of testing shall be increased as follows. In the case that more than 4 % of the inspected weld length has to be repaired, an additional length equal to twice of the original length shall be inspected. If the result of such an additional testing shows again that the work that shall be repaired is greater than 4 % the weld shall be checked on the whole length.

The results of the inspections shall be documented and included in the execution documentation.

12.4.4 Acceptance criteria for welds

12.4.4.1 Structures in service category SC1

The quality levels according to EN ISO 10042 shall be specified. The provisions in Table K.4 should be followed.

Additional information regarding quality levels/acceptance criteria given in Table 10 shall apply.

For the imperfections 2.7 and 2.9 according to EN ISO 10042:2005, the requirements apply if the weld length is more than 25 mm. For shorter weld lengths, these imperfections are not permitted.

The requirements for the following imperfections according to EN ISO 10042:2005 do not apply: 1.4, 1.11, 1.12, 1.14, 1.15, 1.17, 2.2 and 2.5.

Table 10 — Additional requirements for the quality levels of welds, SC1

Reference numbers in accordance with		Deviating quality levels/additional requirements	
EN ISO 10042:2005, Table 1	EN ISO 6520-1:2007	for C	for D
3.2	617	The gap shall be compensated by a corresponding increase in the throat thickness	None
4.1	-	Sum of imperfections shall be short imperfections	

12.4.4.2 Structures in service category SC2

The quality levels according to EN ISO 10042 shall be specified. The following the provisions in Table K.5 should be used. For internal and geometrical imperfections different quality levels may apply.

Additional requirements specified by the designations B+, C+ or D+ are listed in Tables 11, 12 and 13.

NOTE If in EN 1999-1-3 different quality levels apply for geometrical and internal imperfections, the additional requirements for B+, C+ and D+ apply only to these kinds of imperfections where B, C or D is required.

Table 11 — List of additional quality requirements to quality level B of EN ISO 10042:2005 for welds if quality level B+ is specified

Reference numbers in accordance with		Type of imperfection	Maximum limits for imperfection
EN ISO 10042:2005	EN ISO 6520-1:2007		
1.10	5012	intermittent undercut	not permitted
1.11	502	excess weld metal	$H \leq 1,0 + 0,1 b$ max. 4mm
1.18	515	root concavity	not permitted
	5013	shrinkage groove	not permitted
2.3	2011	(single)gas pore	$D \leq 0,15 s$ or $0,15 a$ but max. 3 mm
2.8	303	oxide inclusion	not permitted
2.9	3041	tungsten inclusion	$l \leq 0,15 s$ or $0,15 a$ but max. 2mm
3.1	507	linear misalignment longitudinal welds	$h \leq 0,1 t$ max. 1,5 mm
		circumferential welds	$h \leq 0,1 t$ max. 2 mm
4.1	-	multiple imperfections	not permitted

Table 12 — List of additional quality requirements to quality level C of EN ISO 10042:2005 for welds if quality level C+ is specified

Reference numbers in accordance with		Type of imperfection	Deviating quality levels/ maximum limits for imperfection
EN ISO 10042:2005	EN ISO 6520-1:2007		
1.6	2017	surface pores	B
1.18	515	root concavity	B
	5013	shrinkage groove	B
2.3	2011	(single)gas pore	B
2.8	303	oxide inclusion	B
2.11	402	lack of penetration	not permitted
4.1	-	multiple imperfections	not permitted

Table 13 — List of additional quality requirements to quality level D of EN ISO 10042:2005 for welds if quality level D+ is specified

Reference numbers in accordance with		Type of imperfection	Maximum limits for imperfection
EN ISO 10042:2005	EN ISO 6520-1:2007		
1.2	104	crater cracks	not permitted
1.9	4021	incomplete penetration root	not permitted

12.4.4.3 Friction stir welding

Acceptance criteria for friction stir welding shall be in accordance with EN ISO 25239-5. The bending tests shall not give any fractures.

12.4.5 Acceptance criteria for ultrasonic testing

Acceptance criteria for UT are given in Table 14.

Table 14 — Acceptance criteria for ultrasonic testing of welds

Type of defect	EXC 2	EXC 3 and EXC 4
When echo exceeds the reference curve		
Cracks	Not acceptable regardless of echo height	
Lack of fusion and incomplete penetration	Length max. $2t$ max. 25 mm per 100 mm weld length	Not acceptable
Porosity	Repair is required if porosity may mask other defects	
Oxides or other inclusions	Length max. $2t$ max. 25 mm	Not acceptable
t = thickness NOTE 1 Defect length is defined as the distance between points where the echo reaches or passes 50 % DAC (for defects larger than the beam). For defects smaller than the beam, the maximum amplitude technique may be used. NOTE 2 If elongated defects are situated on line and the distance between them is less than the length of the longest indication, the defects shall be evaluated as one continuous defect. NOTE 3 With UT performed from only one side of the weld with only one surface accessible, the acceptable echo heights are reduced from 100 % to 50 %.		

12.4.6 Repair welds

The original requirements for welds shall be met after any repair or replacement of a nonconformity.

Repaired welds shall be fully inspected by the same methods as for the original welds.

The extent of any defective weld shall be determined by the appropriate inspection procedure and clearly marked on the joint.

Repaired areas shall be stated in the execution documentation.

No joint shall be rewelded, nor any part of a weld repaired more than twice without special approval.

12.4.7 Inspection of temporary attachment locations after removal

Adequate inspection shall be carried out to ensure that the constituent products are not cracked on the surface at the temporary weld location and that the surface has been ground flush.

12.5 Mechanical fasteners

12.5.1 Inspection of connections with non-preloaded bolts

All connections shall be visually checked after tightening of the bolts.

Acceptance criteria and action to correct nonconformity shall be in accordance with 8.3.1 and 9.5.5.

If the nonconformity is due to differing ply thickness that exceeds the criteria specified in 8.1.2, the connection shall be remade. Otherwise nonconformity may be corrected, if possible, by adjusting the local alignment of the component.

If insulation is required between aluminium and other metals, the requirements for checking the installation shall be specified.

Corrected connections shall be reinspected.

12.5.2 Inspection of connections with preloaded bolts

12.5.2.1 Inspection of friction surfaces

If the connections incorporate friction surfaces, the surfaces shall be visually checked immediately before assembly. Acceptance criteria shall be in accordance with 8.1.

Nonconformities shall be corrected in accordance with 8.1.

12.5.2.2 Inspection before tightening

All connections with preloaded bolts 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 8.1.

If the nonconformity is due to differing ply thickness that exceeds the criteria specified in 8.1.2, the connection shall be remade. Otherwise nonconformity may be corrected, if possible, by adjusting the local alignment of the component.

Corrected connections shall be reinspected.

12.5.2.3 Inspection during and after tightening

Inspection and acceptance criteria for bolted joints in slip resistance connections shall be specified.

NOTE EN 1090-2 may be used as a basis for preparation of inspection and acceptance criteria for slip resistance connections.

Retightening of bolts in slip resistance connections is regarded as check of the correct preloading.

Any irregularities shall be recorded, evaluated and if necessary corrections shall be done.

12.5.3 Inspection of riveted connections

100 % of the rivets shall be visually inspected.

A driven rivet shall not show any cracks or pits.

All loose, eccentric headed badly formed or otherwise defective rivets shall be cut out and replaced before the structure is loaded.

12.6 Adhesive bonding

The methods and minimum extent of inspection shall be specified. Any alterations to the specification shall be documented.

12.7 Inspection of the erected structure geometry

The inspection plan shall define which measures to be checked and documented.

12.8 Nonconforming products

12.8.1 Nonconforming constituent products

If the inspection documents for constituent products according to 5.2 have not been provided, the constituent products shall be treated as nonconforming until it can be demonstrated that they meet the requirements of the inspection plan.

If any products are designated as nonconforming and are subsequently proved to be in conformity by test or retest, the testing shall be recorded.

If it can be demonstrated that the nonconforming product can satisfy the requirements for the component or structure in accordance with 12.8.2, the product may be accepted. The evaluation shall be recorded.

12.8.2 Nonconforming components and structures

If it can be documented that the required structural safety, the durability or the functionality is maintained with a nonconforming property of the component or structure, it can be regarded as technically acceptable without need for repair.

NOTE For fitness for purpose, an agreement can be arranged between the parties.

Annex A (normative)

Required additional information, options to be specified and requirements for execution classes

A.1 List of required information

This clause lists in Table A.1, the additional information that is required in the text of this European Standard as appropriate to fully define the requirements for execution of the work to be in accordance with this European Standard (i.e. where the wording "shall be specified" is used).

Table A.1 — List of clauses with subjects, where additional information is necessary

Clause	Subject
4.1.2	The execution class(es) to be applied.
4.2.2	If a quality plan for execution of works is required.
5.1	The constituent products to be used.
5.3	Requirements for testing of cast parts.
5.5	Combination of parent material and welding consumables.
5.6.1	Category of bolted connections, product standards, property classes and any other requirements, e.g. surface treatment.
5.7	Requirement for short and long term behaviour of adhesives.
6.4	If sharp edges shall be removed due to technical reasons.
6.6	Hole sizes.
6.6	Dimensions of any countersinking for bolts.
6.6	Dimensions of any countersinking for rivets.
6.6	Effective length of any slotted holes.
6.9	If a complete assembly check is required.
7.3	If other welding processes than MIG is intended to be used
7.5.1	Requirements for welding if other welding processes than those stated in 7.3 are used.
7.5.5	If welding of temporary attachments is permitted. Locations where temporary attachments are not allowed.
7.5.9	Dimensions for holes for slot and plug welds.
7.5.10	Requirements for other welds, e.g. spot or stud welds, made by other processes than stated in 7.3.
8.1.3	The extent of contact surfaces in slip resistant connections.
8.2.6	The use of normal or oversized washers.

8.5	Method for execution of bonded joints. Requirements for inspection, extent of testing and acceptance criteria.
10.3.1	Nature and extent of all protection measures (surfaces and contact surfaces).
11.1	Any special tolerances.
11.2.3	Tolerance class for shell structures.
12.3.2	Location and frequency of geometrical checks.
12.4.3.1	The minimum extent of inspection and quality requirements for welded joints.
12.4.4.1	The quality requirements for welds for service category SC1.
12.4.4.2	The quality requirements for welds for service category SC2.
12.5.1	Requirements for checking the insulated connections.
12.5.2.3	Non slip resistant bolt connections.

A.2 List of options to be specified

This clause lists the items, for which this European Standard gives one option, however, where alternatively other options might be specified. If no alternative options are specified, the options given in this European Standard apply.

Table A.2 — List of clauses where options might be specified

Clause	Subject
4.2.1	If a quality documentation is required for EXC2.
5.6.1	If surface treatment of mechanical fasteners is specified.
6.6	If removal of burrs for holes drilled in assembled parts is necessary.
7.5.8	If run-on/run-off pieces shall be used for EXC2.
8.2.5	If locking devices for nuts are required.
8.3.1	If locking devices shall be used.
8.3.2	The tightening method for pre-loaded non slip resistant connections.
10.3.2	Corrosion protection on aluminium surfaces in case of contact with aluminium and plastic.
10.3.3	Corrosion protection on aluminium surfaces in case of contact with steel or wood.
10.3.4	Corrosion protection on aluminium surfaces in case of contact with concrete, brickwork and plaster, etc.
10.3.5	Sealing measures for fasteners.
11.2.3.3.2	If shims are allowed to be held in place by welding.
12.4.1	If check of fit-up before welding is required.
12.4.3.1	Any additional tests and testing methods for inspection of welds.
12.4.3.1	Any additional provisions to decide the minimum extent of testing.
12.4.3.2	If destructive testing shall be executed.

A.3 Requirements related to execution classes

This clause gives the requirements that depend on the execution classes.

Table A.3 — Requirements for execution classes

Clause	Heading	Execution class EXC1	Execution class EXC2	Execution class EXC3	Execution class EXC4
4 Specifications and documentation					
4.2.1	Quality documentation	None	If specified	Yes	Yes
5 Constituent products					
5.2	Inspection documents	Test report 2.2	Inspection certificate 3.1	Inspection certificate 3.1	Inspection certificate 3.1
5.2	Traceability	None	None	Yes	Yes
5.2	Marking of alloy and temper	None	Yes, if different alloys and tempers are in circulation together	Yes, if different alloys and tempers are in circulation together	Yes, if different alloys and tempers are in circulation together
6 Preparation					
6.2	Marking or identifying of constituent products	None	Yes, if different alloy and tempers are in circulation together	Yes, if different alloy and tempers are in circulation together	Yes, if different alloy and tempers are in circulation together
6.2	Marking or identifying of parts during manufacturing	None	Yes	Yes	Yes
7 Welding					
7.1	Quality requirements for welding	EN ISO 3834-4 Elementary quality requirements	EN ISO 3834-3 Standard quality requirements	EN ISO 3834-2 Comprehensive quality requirements	EN ISO 3834-2 Comprehensive quality requirements
7.2.1	Welding plan	None	Yes	Yes	Yes
7.4.1	Welding procedures specifications	None	According to EN ISO 15609-1	According to EN ISO 15609-1	According to EN ISO 15609-1
7.4.1	Qualification of arc welding procedures	None	Qualified to EN ISO 15612 or EN ISO 15613 or EN ISO 15614-2	Qualified to EN ISO 15613 or EN ISO 15614-2	Qualified to EN ISO 15613 or EN ISO 15614-2
7.4.4	Welding coordination	None	As defined in EN ISO 14731	As defined in EN ISO 14731	As defined in EN ISO 14731

Clause	Heading	Execution class EXC1	Execution class EXC2	Execution class EXC3	Execution class EXC4
7.4.4	Welding co-ordination personnel	None	Technical knowledge according to Table 7	Technical knowledge according to Table 7	Technical knowledge according to Table 7
7.5.6	Tack welds	None	None	Conditions for deposition of tack welds in WPS	Conditions for deposition of tack welds in WPS
7.5.8	Butt welds	None	Run-on/run-off pieces to ensure full throat thickness if specified	Run-on/run-off pieces to ensure full throat thickness	Run-on/run-off pieces to ensure full throat thickness
8 Mechanical fastening and adhesive bonding					
8.2.5	Locking devices	If specified	If specified	If specified	Shall generally be secured
8.2.5	Assembly of nuts	None	None	Designation markings visible for inspection	Designation markings visible for inspection
12 Inspection, testing and corrections					
12.4.3.1	Test methods	Given in Table 9	Given in Table 9	Given in Table 9	Given in Table 9
The following subjects are given in an informative annex					
K.3.1	Recommended extent of additional NDT in SC1	Given in Table K.2	Given in Table K.2	Given in Table K.2	Given in Table K.2
K.3.2	Recommended extent of additional NDT in SC2	Given in Table K.3	Given in Table K.3	Given in Table K.3	Given in Table K.3

Annex B (informative)

Checklist for the content of a quality plan

B.1 Introduction

In accordance with 4.2.2, this annex gives recommendations for items to be included in the scope of project-specific quality plans for the execution of aluminium structures with reference to the general guidelines in ISO 10005.

B.2 Content

B.2.1 Management

A project management organization plan that names key personnel, their function and responsibilities during the project, the chain of command and lines of communication.

Arrangements for planning and coordination with other parties throughout the project and for monitoring of performance and progress.

Identification of functions delegated to subcontractors and others not in-house.

Identification and proof of competence of qualified personnel to be employed on the project, including welding coordination personnel, inspection personnel, welders and welding operators.

Arrangements for controlling variations, changes and concessions that take place during the project.

B.2.2 Specification review

Requirement to review the specified project requirements to identify the implications including the choices of execution classes and utilization categories that would require additional or unusual measures beyond those assured by the company's quality management system.

Additional quality management procedures necessitated by the review of the specified project requirements.

B.2.3 Documentation

B.2.3.1 General

Procedures to control all received and issued project documentation, including identification of the current revision status and prevention of the use of invalid or obsolete documents in-house or by subcontractors, including drawings, calculations, electronic information and associated registers.

B.2.3.2 Documentation prior to execution

Procedures for providing the required documentation prior to execution of the construction step to which they relate. This will include:

- certificates for constituent products;
- weld procedure specifications and qualification records;
- method statements including those for erection and preloading fasteners;

- design calculations for temporary works necessitated by the erection methods;
- arrangements for scope and timing of second or third party approval or acceptance of documentation prior to execution.

B.2.3.3 Execution records

Procedures for providing execution records, including:

- a) constituent products traced to completed components;
- b) inspection and test reports and action taken to deal with nonconformities, concerning:
 - preparation of joint faces prior to welding;
 - welding and completed weldments;
 - geometrical tolerances of manufactured components;
 - surface preparation and treatment;
 - calibration of equipment including those used for control of preloading of fasteners.
- c) pre-erection survey results leading to acceptance that the site is suitable for erection to commence;
- d) delivery schedules for components delivered to site identified to location in the completed structure;
- e) dimensional surveys of the structure and action taken to deal with nonconformities;
- f) certificates for completion of erection and handover.

B.2.3.4 Storage of records

Arrangements for making documentary records available for inspection, and for retaining them for a minimum period of 5 years, or longer if required by the project.

NOTE National provisions can have more stringent requirements for keeping the records.

B.2.4 Inspection and testing procedures

Identification of the mandatory tests and inspections required by this European Standard and those provided in the constructor's quality system that are necessary for the execution of the project, including:

- a) the scope of inspection;
- b) acceptance criteria;
- c) actions for dealing with nonconformities, corrections and concessions;
- d) release/rejection procedures.

Project-specific requirements for inspection and testing, including requirements that particular tests or inspections are to be witnessed, or points where a nominated third party is to carry out an inspection.

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

РАБОТЕН ДОКУМЕНТ

Annex C (normative)

Cruciform weld test

C.1 Introduction

The purpose of this test is

a) for procedure test for fillet welds (strength and quality);

or

b) for checking material properties for plates made of EN AW-6082, according to 5.3.

C.2 Test piece

The test piece for a welding procedure test for fillet welds shall be prepared and welded according to Figure C.1.

For testing of material properties for plates made of EN AW-6082 only Section I is needed.

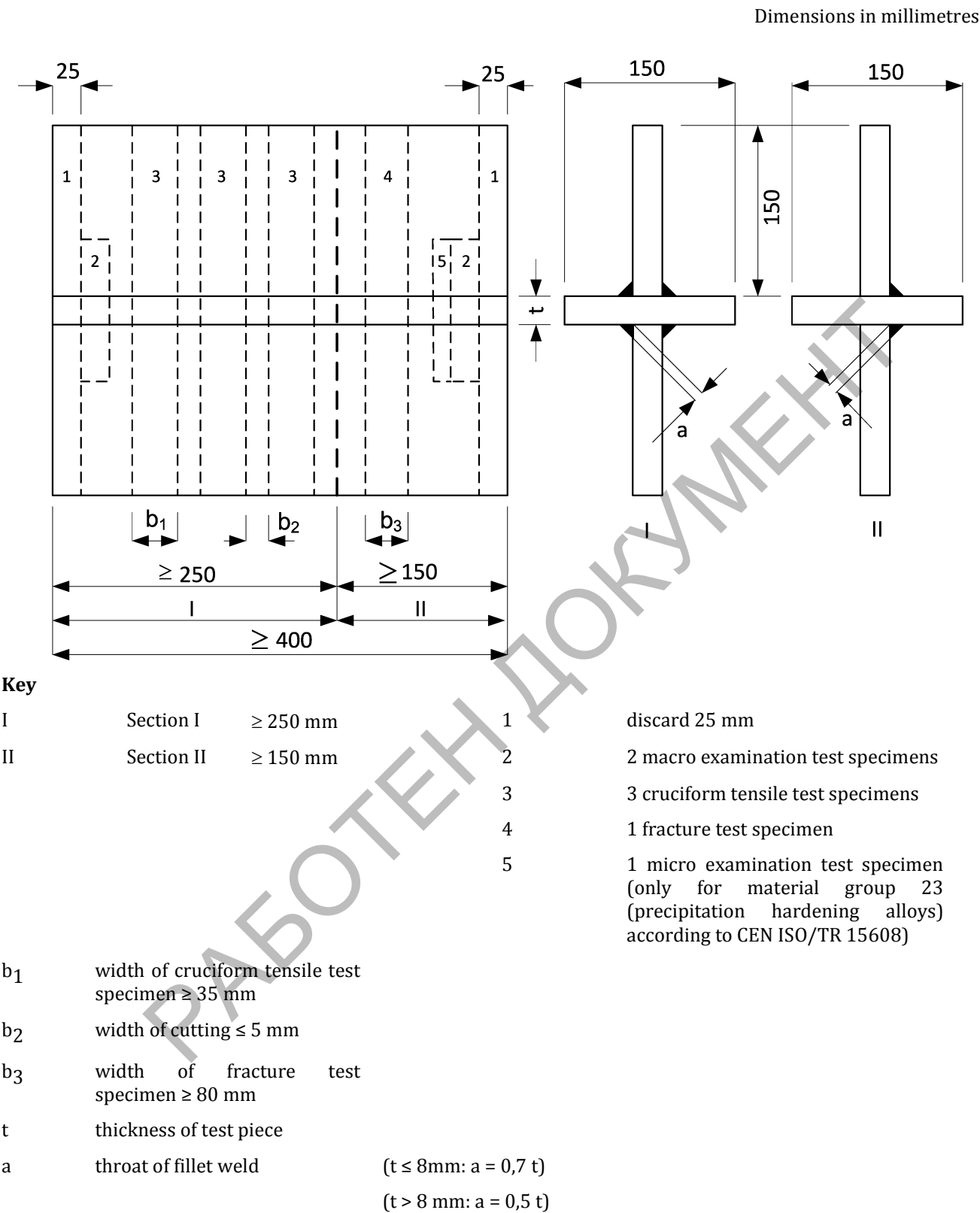


Figure C.1 — Cruciform joint test piece for fillet welds

C.3 Examination and testing

Prior to cutting of the test specimens visual (100 %) and penetrate testing (100 %) shall be carried out.

The fracture test shall be carried out in accordance with EN ISO 9017.

NOTE 1 It is advised to carry out the fracture test prior to the cruciform tensile tests and the macroscopic/microscopic examination.

The cruciform tensile tests shall be carried out in accordance with EN ISO 9018.

For determining the tensile strength of the cruciform joint test specimen the strength of the fillet weld is calculated by determining an average throat thickness a_{eff} for the fillet weld of each test specimen. The tensile strength, defined as $R_{m,test} = N_{m,test}/2a_{eff}$ independent of the fracture mode (HAZ of or throat of the weld), shall fulfil the requirements of Table C.1. If the first test specimen breaks transverse in the HAZ of the parent material, the weld thickness of the following specimens shall be reduced by machining to enforce the fracture in the weld.

NOTE 2 EN ISO 17659 provides guidance on " a_{eff} ".

The test specimens for the macroscopic/microscopic examination shall be prepared and examined in accordance with EN ISO 17639 and shall fulfil the requirements of EN ISO 15614-2. The acceptance levels shall fulfil the requirements of EN ISO 15614-2.

Table C.1 — Minimum strength values for tensile tests with cruciform test specimen (item 3 in Figure C.1) in N/mm²

Alloy designation according to EN 573-3 and EN 573-2		Temper as listed in EN 1999-1-1	Welding consumable according to EN 1999-1-1, alloy designation according to EN ISO 18273		
EN AW-	EN AW-		S-Al 5356/A S-Al 5056A S-Al 5556A/B S-Al 5183/A	S-Al 4043A S-Al 4047A	S-Al 3103
			min R_m (N/mm ²)		
3004	AlMn1Mg1	all	-	-	67
3005	AlMn1Mg0,5	all	-	-	67
3103	AlMn1	all	-	-	67
5005 5005A	AlMg1(B) AlMg1(C)	all	81	-	-
5049	AlMg2Mn0,8	all	153	-	-
5052	AlMg2,5	all	120	-	-
5083	AlMg4,5Mn0,7	all	170	-	-
5454	AlMg3Mn	all	156	-	-
5754	AlMg3	all	153		-
6060	AlMgSi	T66	89	89	-
		T6, T64	81	81	-
		T5	64	64	-
6061	AlMg1SiCu	T6/T651	134	120	-
		T4/T451	121	120	-

Alloy designation according to EN 573-3 and EN 573-2		Temper as listed in EN 1999-1-1	Welding consumable according to EN 1999-1-1, alloy designation according to EN ISO 18273		
EN AW-	EN AW-		S-Al 5356/A S-Al 5056A S-Al 5556A/B S-Al 5183/A	S-Al 4043A S-Al 4047A	S-Al 3103
			min R_m (N/mm ²)		
6063	AlMg0,7Si	T66	105	105	-
		T6	89	89	-
		T5	81	81	-
6005A	AlSiMg(A)	T6	127	113	-
6082	AlSi1MgMn	T6/T651 T61/T6151 T5	149	134	-
		T4/T451	129	129	-
6106	AlMgSiMn	T6	127	113	-
7020	AlZn4,5Mg1	T6/T651	184	149	-
8011A	AlFeSi	all	68	68	-

Annex D (normative)

Procedure for determination of slip factor

D.1 The purpose of testing

The purpose of this testing procedure is to determine the slip factor for a particular treatment, generally involving a surface coating.

The procedure is intended to ensure that account is taken of the possibility of creep deformation of the connection.

D.2 Significant variables

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.

The following variables shall be taken as significant:

- a) composition of the coating;
- b) surface treatment and treatment of primary layers in case of multi-layer systems, see D.3;
- c) maximum thickness of the coating, see D.3;
- d) curing procedure;
- e) minimum time interval between application of the coating and application of load to the connection;
- f) property class of the bolt, see D.6.

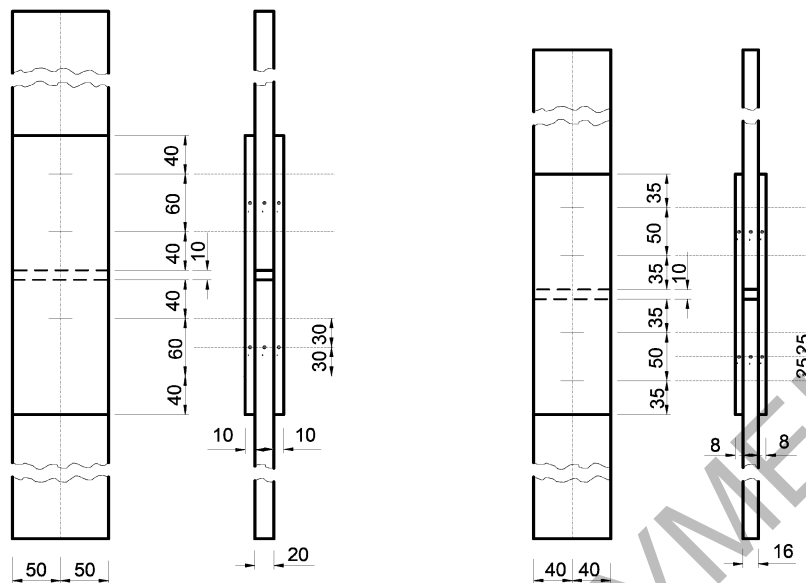
The composition of the coating shall consider the method of application and any thinners used. The curing procedure shall be documented, either by reference to published recommendations or by description of the actual procedure. The time interval (in hours) between coating and testing shall be recorded.

D.3 Test specimens

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

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 8.3.2.



a) M20 bolts in 22 mm diameter holes

b) M16 bolts in 18 mm diameter holes

Figure D.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 specimens shall be assembled such that the bolts are bearing in the opposite direction to the applied tension.

The bolts shall be tightened to within $\pm 5\%$ 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 $\pm 5\%$.

NOTE If it is required to estimate bolt preload losses over time, the test specimens may be left for a specified period at the end of which the preloads may be again measured.

The bolt preloads in each test specimen shall be measured just prior to testing and, if necessary, the bolts shall be retightened to the required $\pm 5\%$ accuracy.

D.4 Slip test procedure and evaluation of results

Test five test specimens. Load four tests at normal speed (duration of test approximately 10 min to 15 min). Use the fifth test specimen for a creep test.

Test the specimens in a tension loading machine. Record the load-slip relationship.

Take the slip as the relative displacement between adjacent points on an inner plate and a cover plate, in the direction of the applied load. Measure it separately for each end of the specimen. For each end, take the slip as the mean of the displacements on both sides of the specimen.

The slip load, F_{Si} , is defined as the load at which a slip of 0,15 mm occurs.

Load the fifth test specimen 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 difference between the recorded slip at 5 min and at 3 h after the application of the load does not exceed 0,002 mm, determine the slip loads for the fifth test specimen as for the first four. If the delayed slip exceeds 0,002 mm, carry out extended creep tests in accordance with D.5.

If the standard deviation, s_{Fs} , of the 10 values (obtained from the five test specimens) for the slip load exceeds 8 % of the mean value, test additional specimens. Determine the total number "n" of test specimens (including the first five) from:

$$n \geq \left(\frac{s}{3,5} \right)^2$$

where

n is the number of test specimens;

s is the standard deviation, s_{Fs} , for the slip load from the first five specimens (10 values) expressed as a percentage of the mean slip load value.

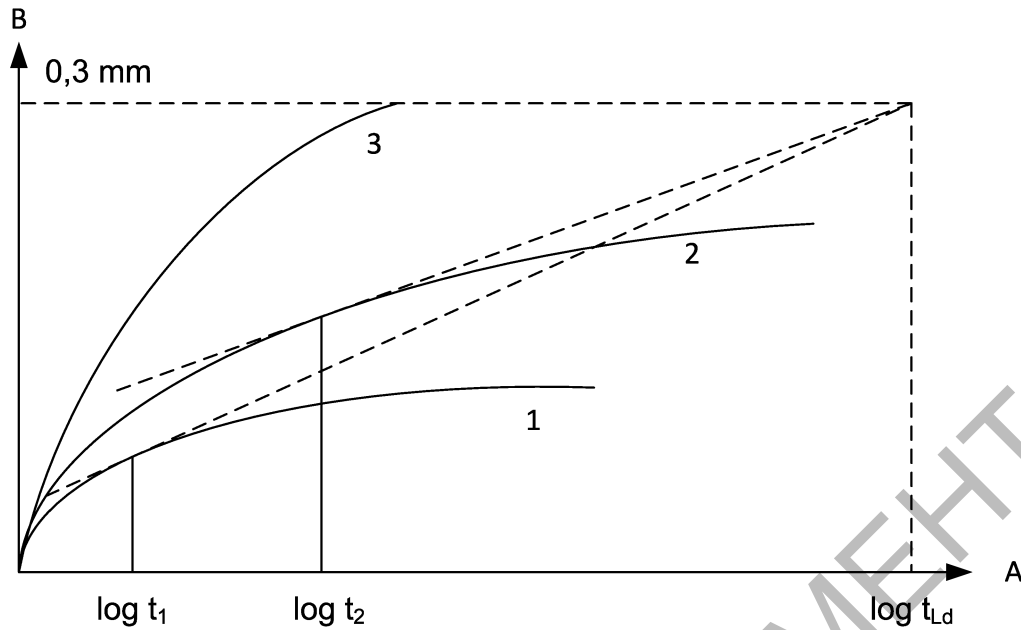
D.5 Extended creep test procedure and evaluation

If it is necessary to carry out extended creep tests following D.4, test at least three test specimens (six connections).

Apply a specific load, determined so as to account both for the result of the creep test carried out in D.4 and for the results of all preceding extended creep tests.

NOTE A load corresponding to the slip factor proposed for use in the structural application may be adopted. If the surface treatment is to belong to a specified class, a load corresponding to the slip factor for that class may be used.

Plot a 'displacement - log time' curve (see Figure D.2) to demonstrate that the load determined using the proposed slip factor will not cause displacements greater than 0,3 mm during the life of the structure, taken as 50 years unless specified otherwise. The 'displacement - log time curve' may be extrapolated linearly as soon as the tangent can be determined with sufficient accuracy.

**Key**

t_1 minimum duration for test 1

t_2 minimum duration for test 2

t_{Ld} design life of structure

A log time (years)

B Displacement (millimetre)

The loading (slip factor) for test 3 is set too high.

Figure D.2 — Use of the displacement - log time curve for extended creep test

D.6 Test results

Individual slip factor values are determined as follows:

$$\mu_i = \frac{F_{Si}}{4F_{p,C}}$$

The slip load mean value F_{Sm} and its standard deviation s_{Fs} are determined as follows:

$$F_{Sm} = \frac{\sum F_{Si}}{n}$$

$$s_{Fs} = \sqrt{\frac{(F_{Si} - F_{Sm})^2}{n - 1}}$$

The slip factor mean value μ_m and its standard deviation s_μ are determined as follows:

$$\mu_m = \frac{\sum \mu_i}{n}$$

$$s_{\mu} = \sqrt{\frac{(\mu_i - \mu_m)^2}{n-1}}$$

The characteristic value of the slip factor μ shall be taken as the 5 % fractile value with a confidence level of 75 %.

For 10 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.

For extended creep test, the nominal slip factor may be taken as the value demonstrated to satisfy the specified creep limit (see D.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 class as follows, in accordance with the characteristic value of the slip factor μ determined in D.4 or D.5 as relevant:

$\mu \geq 0,50$	friction class A;
$0,40 \leq \mu \leq 0,50$	friction class B;
$0,30 \leq \mu \leq 0,40$	friction class C;
$0,20 \leq \mu \leq 0,30$	friction class D.

Annex E (informative)

Surface treatment

E.1 Anodic oxidation

If not otherwise specified, a minimum thickness of the oxide layer of 20 µm is required if it is to be used as corrosive protection. Special requirements for the appearance should be agreed.

A method for specifying decorative and protective anodic oxidation coatings on aluminium is given in EN ISO 7599.

NOTE Quality assurance and quality assessment can be done in the framework of a recognized European quality programme.

E.2 Coatings

E.2.1 General

The surfaces to be protected should be cleaned using suitable equipment such as fibre brushes, cleaning wool, careful abrasive-blast cleaning using suitable blasting material and thereafter carefully degreased (e.g. using organic grease dissolving agent, or aqueous purifying agent without leaving residuals). In special cases, stainless steel and copper free brushes can be used. Cleaning and degreasing is also possible by proved chemical pre-treatment methods (e.g. etching, see also EN 12487). Corrosion should be removed. Flame cleaning is not allowed. Welds should be brushed to a metal bright finish.

NOTE 1 Abrasive blast only if the thickness is > 3 mm. Suitable blasting shot or grit are e.g. aluminium, corundum (no regenerate), glass. Examples of unsuitable blasting materials are steel, iron and copper. For other blasting materials, the suitability for aluminium needs to be proved, e.g. they need to be free from iron, copper and nickel.

If sheets, profiles or parts of the structure already have been pre-treated or primed before assembly, all parts that were in contact with grease should be cleaned once more with a suitable method before subsequent coats are deposited.

Coating of the whole structure should be carried out before or directly after the assembly.

Execution of coatings should only be done when the surface temperature of the parts to be coated is higher than 5 °C, relative humidity is less than 85 % and the surface temperature is 3 °C above the dew point, unless other limits are permitted by the manufacturer of the coating.

It should be ensured that the use of pre-coated material or factory applied finishes affords the protection appropriate to the assembly and to the environment.

Care should be taken when using coating systems to be dried by heat treatment. Temperatures of stove lacquering and drying time should not exceed material specific limits, which are to be defined by the manufacturer of the semi products.

NOTE 2 Aluminium materials may be supplied ready painted, using either a solvent based liquid or a dry (powder coating) process. The finish can be applied prior to preparation, to partly prepared material, or following preparation. Liquid coatings are usually cured by stoving at an elevated temperature. Powder coatings are always cured by stoving. In both cases the stoved coatings will have improved properties with regard to hardness and durability compared to an air-dried coating. Such finishes are suitable for application on strip, coil or extruded sections. The coating may be ductile enough to permit slight deformation without damage, as by press-braking or

by roll forming. The use of factory applied finishes and pre-coated materials, generally provides an acceptable degree of protection.

NOTE 3 Most factory applied finishes are cured by heating to about 180 °C or slightly more for a short time, which normally has only low effects on the mechanical properties. It is however possible for significant weakening to occur, depending on the alloy, its condition and also on the temperature profile of the stoving process. Routine thermal monitoring is normal practice and is particularly important with thick sections, where there is more risk of under or over curing. A report on the thermal history of the metal from a suitable cure monitoring system is recommended.

NOTE 4 Specification, quality assurance and quality assessment can be done in the framework of recognized European quality programmes.

For powder coatings, see EN 12206-1.

For coil coating, see EN 1396

E.2.2 Pre-treatment

Directly after drying a suitable priming coat should be deposited onto the cleaned and degreased surfaces if these are not already pre-treated in another way.

NOTE 1 A suitable priming coat can be a conversion coating or an etch-primer or wash primer, provided that the metal surface is clean and free from thick or irregular oxide coatings.

For chromating, EN 12487 should be followed.

The application of chromate free conversion coatings should be specified.

NOTE 2 Specification, quality assurance and quality assessment can be done in the framework of recognized European quality programmes.

Unsealed anodization is also suitable as a pre-treatment.

E.2.3 Base coat

Pre-treated surfaces should be covered with a base coat with an appropriate inhibiting pigment compatible with the aluminium substrate and any subsequent coats. Lead, copper, mercury or tin, graphite, cadmium or carbonaceous materials as pigments are not allowed in basic coatings.

E.2.4 Final coat

After sufficient drying of the base coat, a suitable final coat should be applied depending on the exposure conditions. The final coat should not contain lead, copper, mercury or tin, graphite, cadmium or carbonaceous materials as pigments (for coating of contact areas of structural parts, see 10.3) and should be compatible with the base coat or any subsequent coats.

E.2.5 Coatings with bitumen or bituminous combinations

The bitumen coating materials should be neutral, e.g. bitumen.

The surfaces to be coated should be bare. If necessary they should be cleaned and carefully degreased but have not to be pre-treated with a primer.

E.2.6 Repair coatings

The surface should be cleaned from dirt before repair coating. Damaged parts of the existing coating should be removed; parts of the coating-sticking surface can be left. Afterwards the surface should be brushed with a fibre brush.

A smooth passing between existing coating and the plain metal should be prepared. Corrosion should be cleaned off. Removal by caustics attacking the metal, flame cleaning and mechanical removal using striking tools are not allowed.

Plain metal should be pre-treated with a primer and then base coating and final coating should be applied.

E.3 Passivation

Any required passivation or special surface treatment should be specified. The requirements for the application published by the manufacturer of the passivation agent should be followed. If the required type of passivation is not specified, the minimum should be a chromic acidic solution (for chromating, see also EN 12487) or if possible, phosphoric acidic solution (phosphating).

NOTE Passivation of aluminium without additional coating is only a short-term protection or for mild conditions.

Annex F (normative)

Geometrical tolerances – Essential tolerances

F.1 Manufacturing tolerances

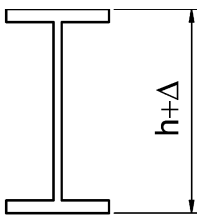
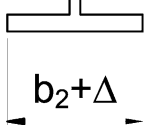
F.1.1 General

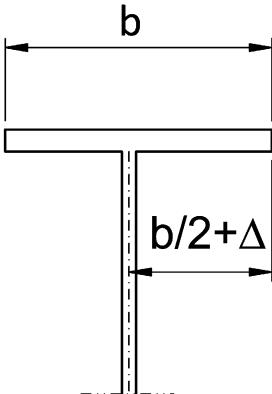
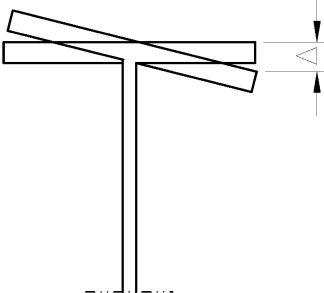
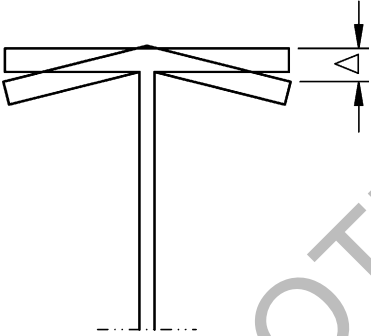
The manufacturing tolerances given in this clause apply to all types of components and structures.

F.1.2 Welded I-sections

The deviations of welded I-sections from the specified cross-sectional dimensions shall not exceed the values given in Table F.1.

Table F.1 — Permitted deviations for welded I-sections

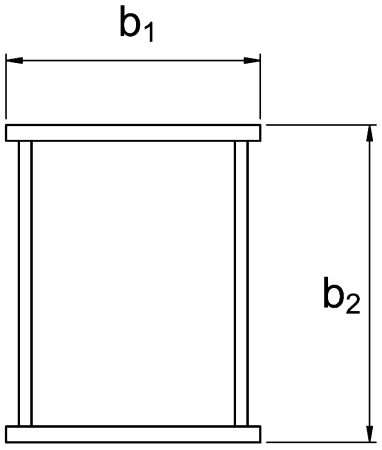
Case	Type of deviation	Dimensional parameter	Permitted deviation
A	Depth: 	Depth of section: $h \leq 900 \text{ mm}$ $900 < h \leq 1\,800 \text{ mm}$ $h > 1\,800 \text{ mm}$	$\Delta = \pm 3 \text{ mm}$ $\Delta = \pm 5 \text{ mm}$ $\Delta = + 8 \text{ mm or } - 5 \text{ mm}$
B	Flange width: $b_1 + \Delta$  $b_2 + \Delta$ 	Width b_1 or b_2 : $b < 300 \text{ mm}$ $b \geq 300 \text{ mm}$	$\Delta = \pm 3 \text{ mm}$ $\Delta = \pm 5 \text{ mm}$

C		Position of web:	$\Delta = b/50$ but not less than 2 mm
D		Out of squareness:	$\Delta = b/50$ but not less than 2 mm
E		Out of flatness:	$\Delta = b/50$ but not less than 2 mm

F.1.3 Welded box sections

The deviations of welded box sections from the specified cross-sectional dimensions shall not exceed the values given in Table F.2.

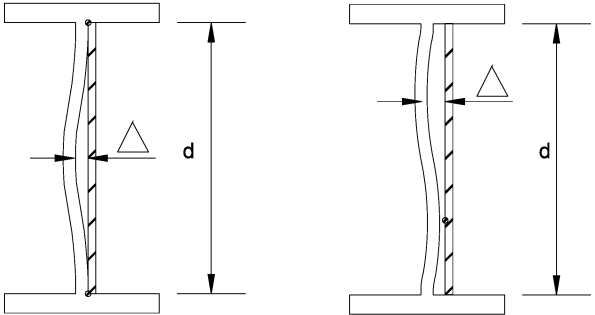
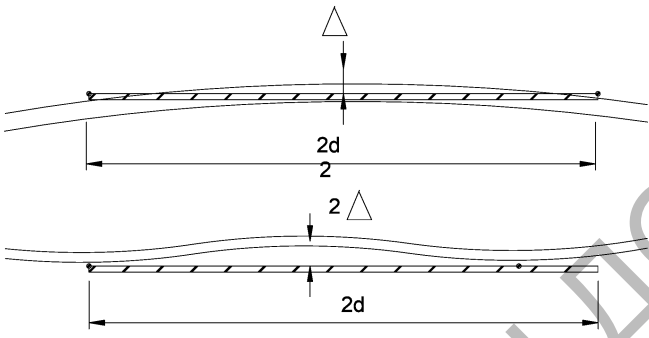
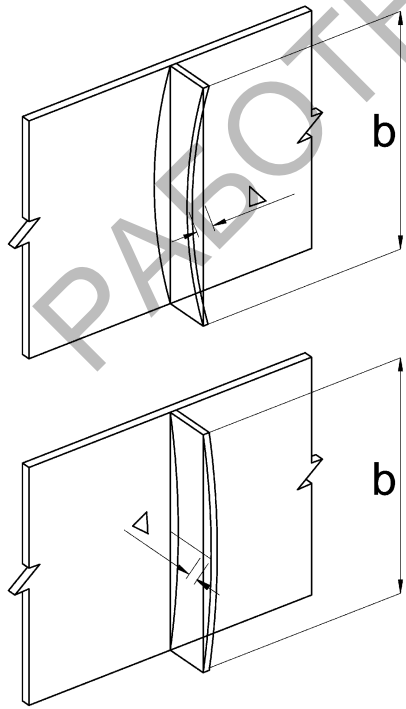
Table F.2 — Permitted deviations for welded box sections

Case	Type of deviation	Dimensional parameter	Permitted deviation
A	Section dimensions: 	Deviation Δ in the widths of an individual plate: $b_i \leq 300 \text{ mm}$ $b_i > 300 \text{ mm}$ where $i = 1$ or 2	$\Delta = \pm 3 \text{ mm}$ $\Delta = \pm 5 \text{ mm}$
NOTE The deviation for plate stiffeners the values of Table F.3, case B apply.			

F.1.4 Webs

The distortion of webs shall not exceed the values given in Table F.3. The permitted deviation for web distortion also applies to flange distortion.

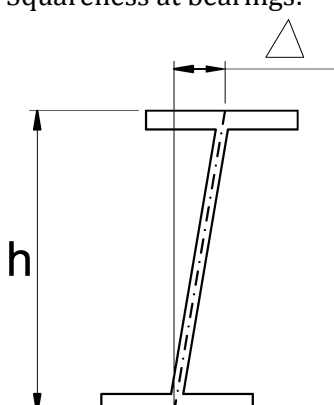
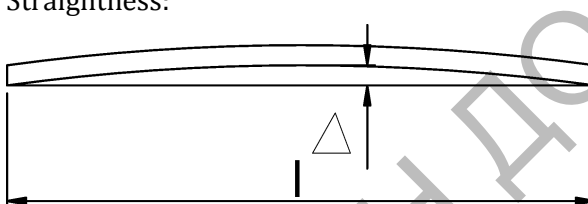
Table F.3 — Permitted deviations for webs

Case	Type of deviation	Dimensional parameter	Permitted deviation
A	Web distortion: Cross section:  Longitudinal view: 	Distortion Δ on web depth and length: $\frac{d}{t} \leq 50$ $50 < \frac{d}{t} < 100$ $\frac{d}{t} \geq 100$ t = thickness of web	$\Delta < \frac{d}{200}$ $\Delta < \frac{d^2}{10000t}$ $\Delta < \frac{d}{100}$
B	Web stiffeners: 	Deviation Δ from straightness in the plane of the web: For $b \leq 750$ mm For $b > 750$ mm Deviation Δ from straightness normal to the plane of the web: For $b \leq 1\,500$ mm For $b > 1\,500$ mm	$\Delta = 3$ mm $\Delta = b/250$ $\Delta = 3$ mm $\Delta = b/500$

F.1.5 Components

The deviations of the squareness of components from the specified dimensions shall not exceed those shown in Table F.4.

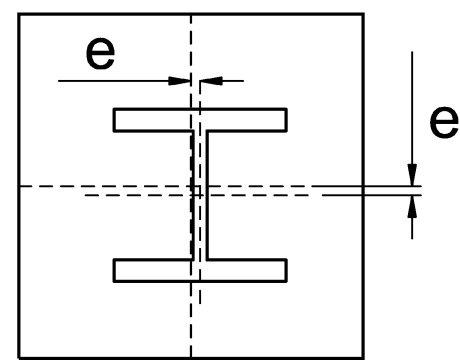
Table F.4 — Permitted deviations for components

Case	Type of deviation	Dimensional parameter	Permitted deviation
A	Squareness at bearings: 	Verticality of web at supports, for components without bearing stiffeners:	$\Delta = b/300$ but not less than 3 mm
B	Straightness: 	Straightness on both axes:	$\Delta = b/750$ but not less than 3 mm

F.1.6 Base plates and end plate connections

The non-intended eccentricity of a base plate and end plate connections for all types of connections shall not exceed the values given in Table F.5. The permitted deviations for base plates and end plate connections apply also to cap-plates.

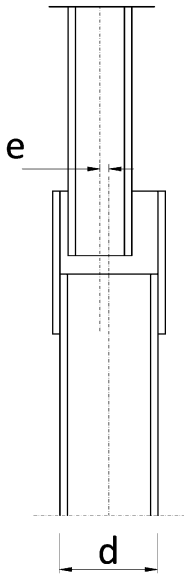
Table F.5 — Permitted deviations for base plates and end plate connections

Case	Type of deviation	Dimensional parameter	Permitted deviation
A	Base plate and end plate connections (apply also to cap-plates): 	Non-intended eccentricity e :	$e = 5 \text{ mm}$

F.1.7 Column splices

The non-intended eccentricity of a column at a splice for all types of connections shall not exceed the values given in Table F.6.

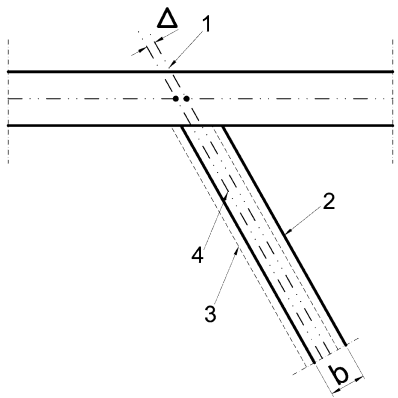
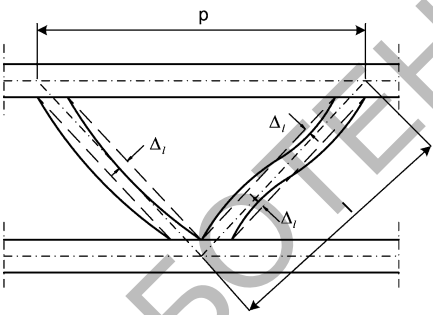
Table F.6 — Permitted deviations for column splices

Case	Type of deviation	Dimensional parameter	Permitted deviation
A	Column splice: 	Non-intended eccentricity e (about either axes): d = depth of the deepest section	e = less of $d/50$ and 5 mm, but not less than 2 mm

F.1.8 Lattice components

The deviations of manufactured lattice components shall not exceed the values given in Table F.7.

Table F.7 — Permitted deviations for manufactured lattice components

Case	Type of deviation	Dimensional parameter	Permitted deviation
A	Joint eccentricity:  1 centre line of actual location 2 actual location 3 intended location 4 centre line of intended location	Joint eccentricity: — Eccentricity at joint ^a <i>b</i> is nominal cross sectional dimension of bracing in mm	$\Delta = b/20 + 5 \text{ mm}$
B	Lattice components after welding:  NOTE For the straightness of the upper and lower chords, see Table F.4 case B	Deviation of individual distances, <i>p</i>, between intersections of centre lines at panel points. Cumulative dimension, $\Sigma \Delta_p$, of panel point position Straightness of bracing, deviation from centreline from a straight line: $l < 1\,500 \text{ mm}$ $l \geq 1\,500 \text{ mm}$	$\Delta_p = \pm 5$ $\Sigma \Delta_p = \pm 10 \text{ mm}$ $\Delta_l = 3 \text{ mm}$ $\Delta_l = l/500$ but not greater than 6 mm

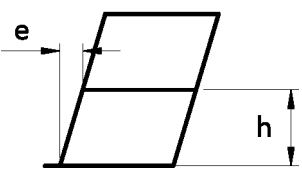
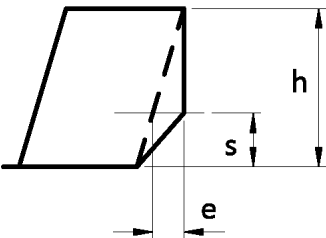
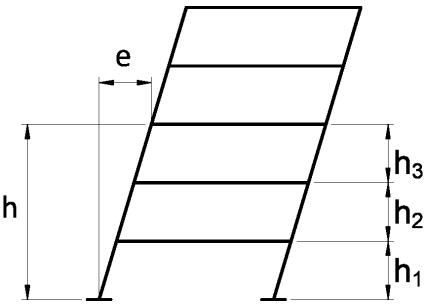
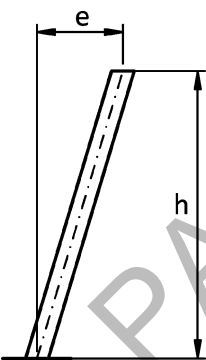
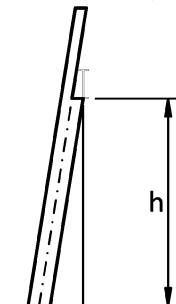
^a Deviation is measured relative to any eccentricity specified.

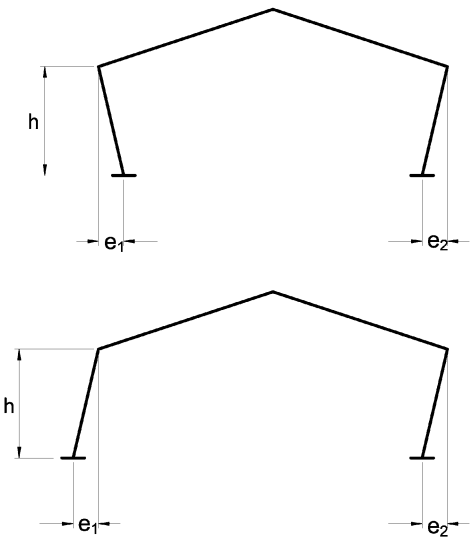
F.2 Erection tolerances

F.2.1 Columns

The deviations of columns/vertical members shall not exceed the values in Table F.8.

Table F.8 — Permitted deviations for columns

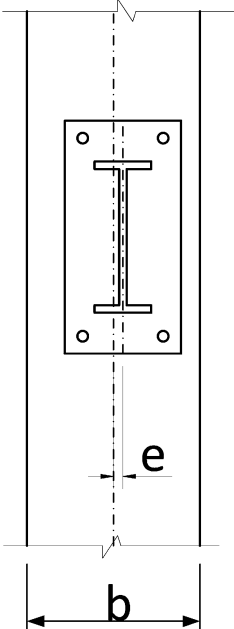
Case	Type of deviation	Dimensional parameter	Permitted deviation
A		Inclination of a column between adjacent storey levels in a multi-storey structure:	$e = \pm h/500$
B		Location of a column splice compared to a straight line joining connection points at adjacent storey levels in a multi-storey structure:	$e = \pm s/500$ $s \leq h/2$
C		Location of a column at any storey level, from a vertical line through its centre at base level in a multi-storey structure: n is the number of storeys	$e = \frac{\sum h_i}{300 \cdot \sqrt{n}}$
D		Inclination of a column in a single-storey building. For columns supporting a crane gantry see case E.	$e = \pm h/300$
E		Inclination of a column supporting a crane gantry, including columns of portal frames:	

		$h < 5 \text{ m}$ $5 \text{ m} \leq h \leq 25 \text{ m}$ $h > 25 \text{ m}$	$e = \pm 5 \text{ mm}$ $e = \pm h/1\,000$ $e = \pm 25 \text{ mm}$
F		Inclination of columns of a portal frame not supporting a crane gantry: — Inclination of individual columns — Where both columns of a frame lean in the same direction, the mean inclination of columns	$e = \pm h/100$ $(e_1 + e_2)/2 = \pm h/500$

F.2.2 Beams

The non-intended eccentricity of a beam connected to a column, measured relative to the column, shall not exceed the value given in Table F.9.

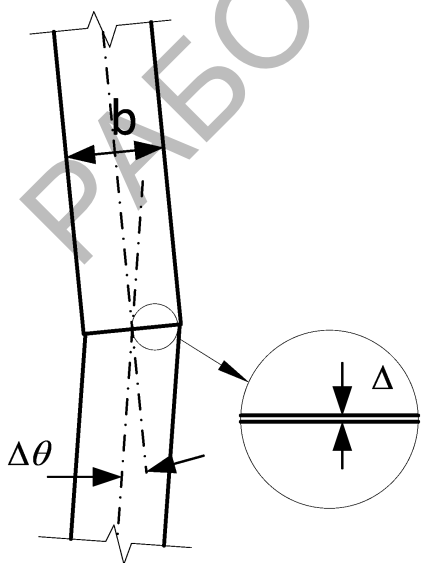
Table F.9 — Permitted deviations for beam to column connections

Case	Type of deviation	Dimensional parameter	Permitted deviation
A		Location of a beam-to-column connection, measured relative to the specified position:	$e = \text{less of } d/50 \text{ and } 5 \text{ mm, but not less than } 2 \text{ mm}$

F.2.3 Full contact bearing

Where full contact bearing is specified in bolted splices, the fit-up between surfaces of erected components shall be in accordance with Table F.10 after alignment and bolting-up.

Table F.10 — Permitted deviations from full contact bearing

Case	Type of deviation	Dimensional parameter	Permitted deviation
A	 $\Delta\theta$ shall be in accordance with Table F.8 case B before the gap is measured.	Air gap	$\Delta \leq 1,0 \text{ mm}$ over at least $2/3$ of the contact area Max. $\Delta \leq 2,0 \text{ mm}$ locally

Annex G (normative)

Geometrical tolerances - Functional tolerances

G.1 General

For commonly used components and structural details, this annex gives types of geometrical deviations relevant to the execution of aluminium structures, and gives permitted values for functional tolerances.

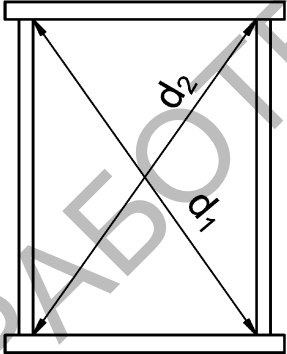
Geometrical deviations relevant to the structural integrity of aluminium structures are given in Annex F. The permitted values are for acceptance testing of the completed structure.

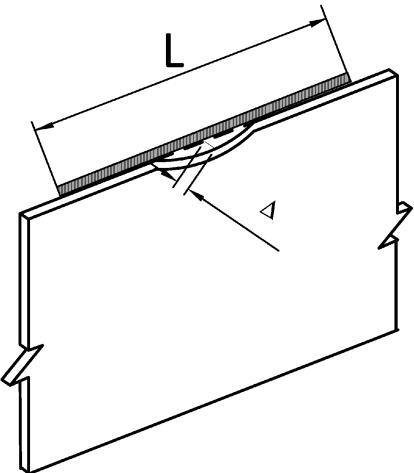
G.2 Manufacturing tolerances

G.2.1 Box sections

The deviations of manufactured box sections from the distortion of the plates and the deviations in the straightness of plate stiffeners shall not exceed the values given in Table G.1.

Table G.1 — Permitted deviations for box sections

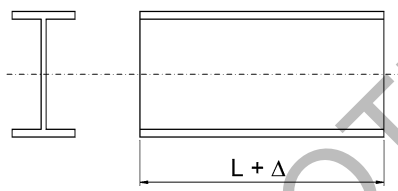
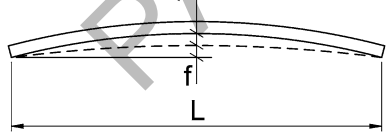
Case	Type of deviation	Parameter	Permitted deviation
A	Squareness: (at diaphragm positions) 	Difference between nominally similar diagonal distances: $\Delta = (d_1 - d_2)$:	$ \Delta = \text{greater of}$ $(d_1 + d_2)/400$ and 5 mm

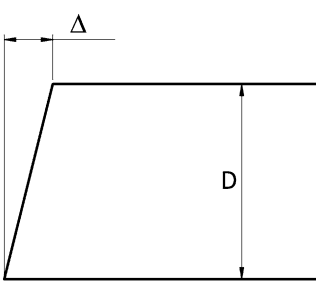
B	Plate distortion:  Gauge length L = web height b	Distortion Δ on plate width or gauge length:	$ \Delta $ = greater of $b/150$ and 4 mm
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G.2.2 Components

The deviations of the length, straightness, camber and squareness of components from the specified dimensions shall not exceed those shown in Table G.2.

Table G.2 — Permitted deviations for components

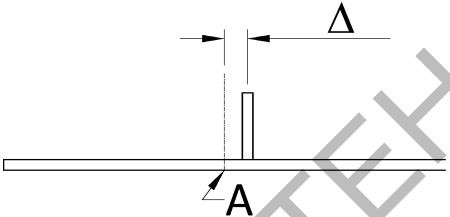
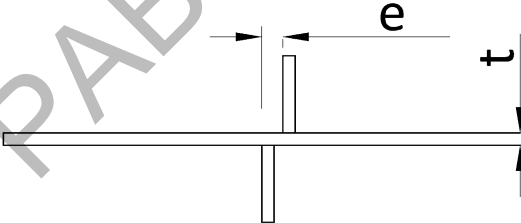
Case	Type of deviation	Parameter	Permitted deviation
A	Length: 	Length measured along the centre line or along a corner of the section at a given temperature: — cut length — component with both ends finished for full contact bearing including end plates as applicable	$\Delta = \pm (2 \text{ mm} + L/5000)^a$ $\Delta = \pm 2 \text{ mm}$
B	Camber: 	Camber f at mid-length, measured with the web horizontal:	$ \Delta $ = greater of $L / 750$ and 6 mm

C	Squareness of ends:  This values are also valid for inclined end faces.	Squareness to longitudinal axis: — not finished for full contact bearing — finished for full contact bearing D is depth/section height in mm	$\Delta = \pm D/300$ $\Delta = \pm D/1\,000$
a The length L shall be taken in mm.			

G.2.3 Stiffeners

The deviations in the locations of stiffeners shall not exceed the values given in Table G.3.

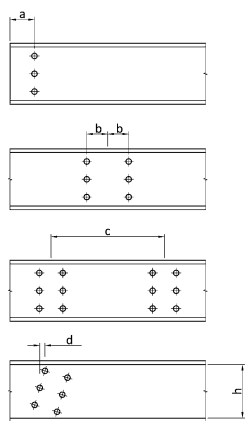
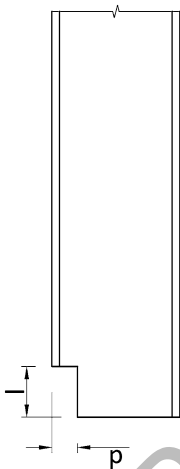
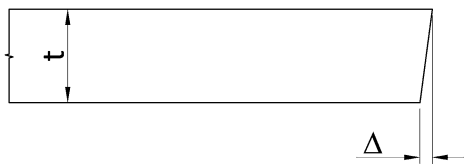
Table G.3 — Permitted deviations for stiffeners

Case	Type of deviation	Parameter	Permitted deviation
A	Location of stiffeners:  A = Intended location 	Deviation Δ from the intended location: Eccentricity e between a pair of stiffeners:	$\Delta = \pm 5 \text{ mm}$ $e = t/2$ but not less than 3 mm

G.2.4 Fastener holes, notches and edges

The deviations of the locations of fasteners holes, the dimensions of notches and the squareness of cut edges shall not exceed the values given in Table G.4.

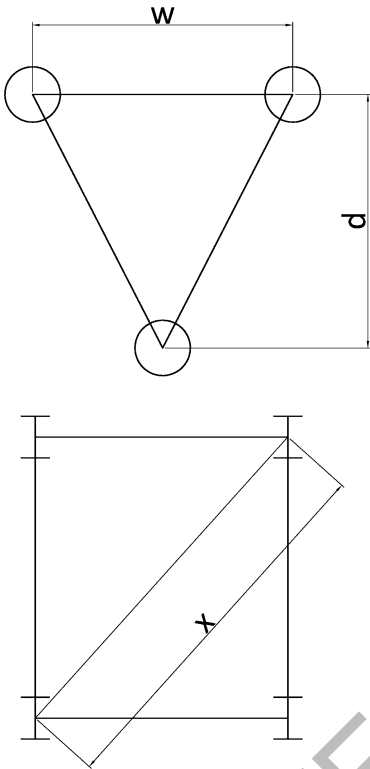
Table G.4 — Permitted deviations for holes, notches and edges

Case	Type of deviation	Parameter	Permitted deviation
A	Position of groups of fasteners holes: 	Deviation Δ of a group of holes from their intended position: — Dimension a — Dimension b — Dimension c — Dimension d — if $h \leq 1\,000\text{ mm}$ — if $h > 1\,000\text{ mm}$	$\Delta = + 5\text{ mm} / - 0\text{ mm}$ $\Delta = \pm 2\text{ mm}$ $\Delta = \pm 5\text{ mm}$ $\Delta = \pm 2\text{ mm}$ $\Delta = \pm 4\text{ mm}$
B	Notches: 	Deviation Δ of the main notch dimensions: — Dimension d — Dimension l	$\Delta = + 2\text{ mm} / - 0\text{ mm}$ $\Delta = + 2\text{ mm} / - 0\text{ mm}$
C	Free edges: 	Deviation Δ of a cut edge from 90° : t thickness in mm	$\Delta = \pm 0,1 t$, maximum 3 mm

G.2.5 Lattice components

The deviations of manufactured lattice components shall not exceed the values given in Table G.5.

Table G.5 — Permitted deviations for manufactured lattice components

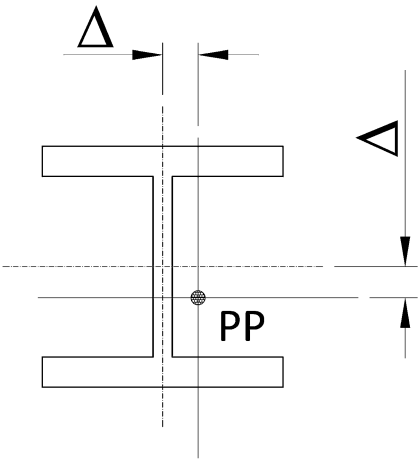
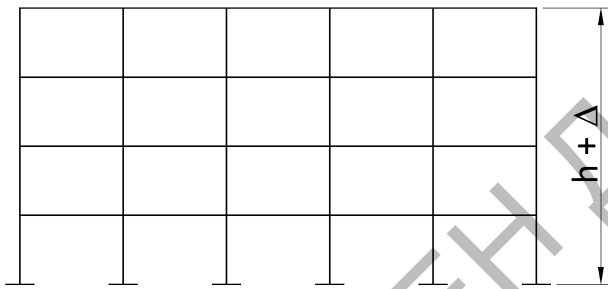
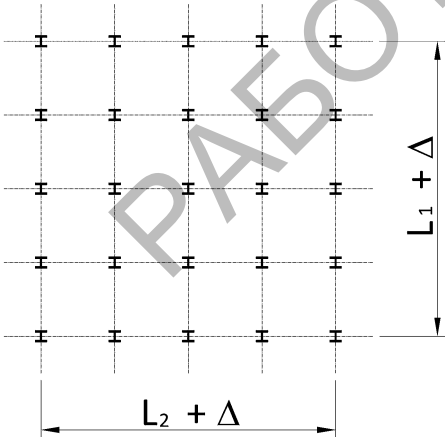
Case	Type of deviation	Parameter	Permitted deviation
A	Overall lattice cross-sections: 	Deviation of distances d , w and x if: $s \leq 300 \text{ mm}$ $300 \text{ mm} < s < 1\,000 \text{ mm}$ $s \geq 1\,000 \text{ mm}$ where $s = d, w$ or x as appropriate d means depth w means width x means diagonal	$\Delta = \pm 3 \text{ mm}$ $\Delta = \pm 5 \text{ mm}$ $\Delta = \pm 10 \text{ mm}$

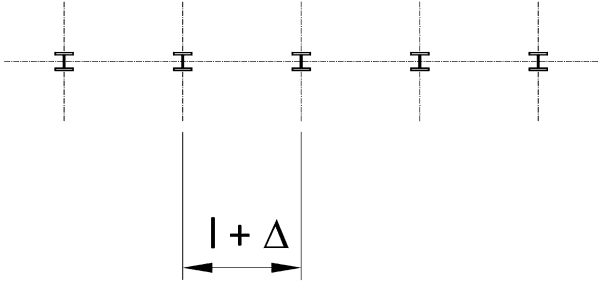
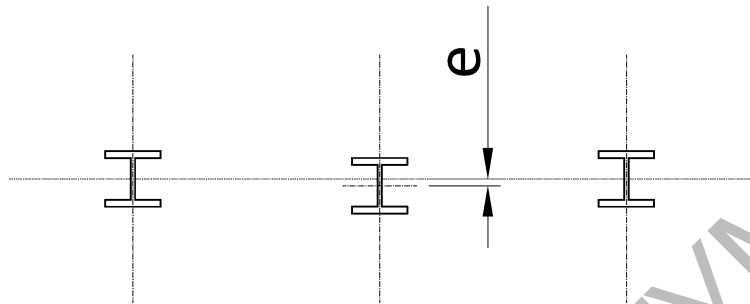
G.3 Erection tolerances

G.3.1 Columns

The deviations of columns/vertical members shall not exceed the values in Table G.6.

Table G.6 — Permitted deviations for columns

Case	Type of deviation	Parameter	Permitted deviation
A		Position in plan of the centre of an aluminium column at its base relative to its position point (PP):	$\Delta = \pm 5 \text{ mm}$
B		Overall height of columns measured relative to base level: $h \leq 20 \text{ m}$ $20 \text{ m} < h < 100 \text{ m}$ $h \geq 100 \text{ m}$	$\Delta = \pm 10 \text{ mm}$ $\Delta = \pm 0,25(h + 20) \text{ mm}$ $\Delta = \pm 0,1(h + 200) \text{ mm}$ h in meter
C		Distance between end columns in each line at base level: $L \leq 30 \text{ m}$ $30 \text{ m} < L < 250 \text{ m}$ $L \geq 250 \text{ m}$	$\Delta = \pm 20 \text{ mm}$ $\Delta = \pm 0,25(L + 50) \text{ mm}$ $\Delta = \pm 0,1(L + 500) \text{ mm}$ L in meter

D		Distance between adjacent columns:	$\Delta = \pm 10 \text{ mm}$
E		Location of a column at base and storey level compared to a line joining adjacent columns:	$e = \pm 10 \text{ mm}$

G.3.2 Beams, rafters and trusses

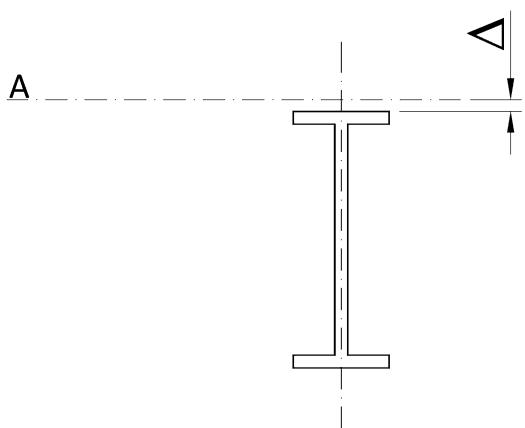
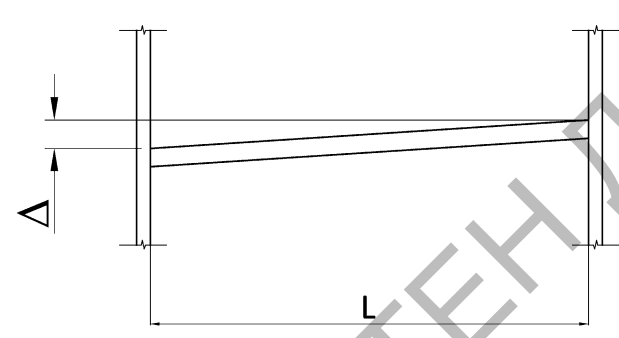
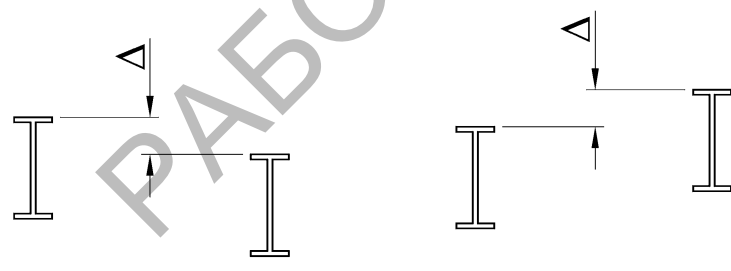
The levels of beams are measured relative to the as-built storey levels, which are best fits to the required level adjusted for tolerances in the column lengths.

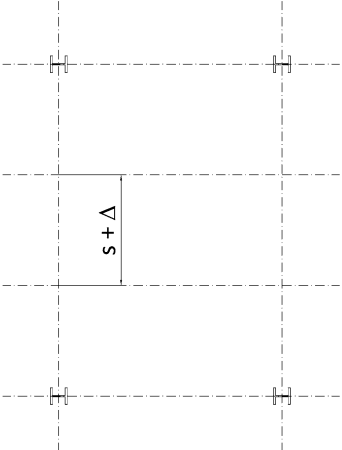
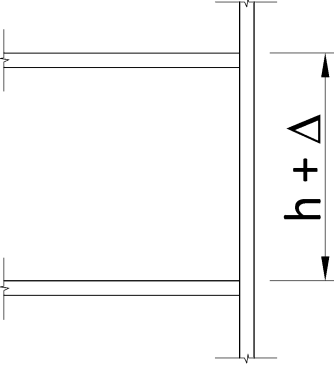
The permitted deviation at mid span for the camber of an erected beam is $\text{span}/500$ measured relative to its support points.

The permitted deviation for the camber of an erected truss spanning over 20 m and assembled on site is $\text{span}/300$ measured relative to its support points.

The permitted deviation for the pre-set of the end of a cantilever beam is $\text{length}/300$ measured relative to its support point.

Table G.7 — Permitted deviations for beams

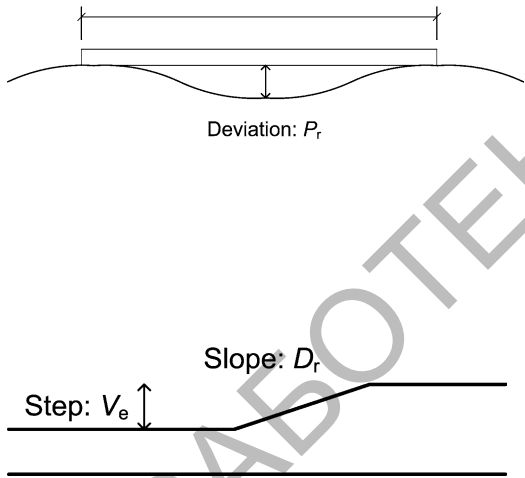
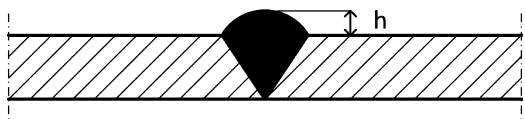
Case	Type of deviation	Parameter	Permitted deviation
A	 A = As built level	Level of a beam at a beam-to-column connection, measured relative to the as-built storey level:	$\Delta = \pm 10 \text{ mm}$
B		Level at opposite end of beam:	$\Delta = \text{smaller of } L/500 \text{ and } 10 \text{ mm}$
C		Level at adjacent beams, measured at corresponding ends:	$\Delta = \pm 10 \text{ mm}$

D		Distance between adjacent beams, measured at corresponding ends:	$\Delta = \pm 10 \text{ mm}$
E		Levels at adjacent floors:	$\Delta = \pm 10 \text{ mm}$

G.4 Bridges

The following requirements to deviations for bridges apply in addition to the other tolerances given in Annex F and Annex G.

Table G.8 — Permitted deviations specific for bridges

Case	Type of deviation	Dimensional parameter	Permitted deviation
A	Span length	Deviation, Δ , of distance, L , between two consecutive supports measured on top of upper flange: NOTE The effective value for the distance between supports may also be directly measured if this is of advantage.	$\Delta = \pm 3 \cdot L / 1\,000$
B	Bridge elevation or plan profile	Deviation, Δ , from nominal profile adjusted for as-built levels of supports: $L \leq 20$ m: $L > 20$ m:	$\Delta = \pm L / 1\,000$ $\Delta = \pm L / 2\,000 + 10$ mm, but less than or equal to ± 35 mm
C	Fit-up of orthotropic decks of plate/profile thickness, T , after erection: Gauge length: L 	Flatness in all directions: $T \leq 10$ mm: $T > 70$ mm: — General case: — Longitudinal: NOTE Values for P_r may be interpolated for $10 \text{ mm} < T \leq 70 \text{ mm}$ Difference in level (step) at junction: $T \leq 10$ mm: $10 \text{ mm} < T \leq 70 \text{ mm}$: $T > 70$ mm: Slope at junction: $T \leq 10$ mm: $10 \text{ mm} < T \leq 70 \text{ mm}$: $T > 70$ mm:	$P_r = 3$ mm over 1 m $P_r = 4$ mm over 3 m $P_r = 5$ mm over 5 m $P_r = 5$ mm over 3 m $P_r = 18$ mm over 3 m $V_e = 2$ mm $V_e = 5$ mm $V_e = 8$ mm $D_r = 8 \%$ $D_r = 9 \%$ $D_r = 10 \%$
D	Orthotropic deck welding: 	Protrusion, h , of weld above surrounding surface:	$h = + 1 / - 0$ mm

Annex H (normative)

Geometrical tolerances – Shell structures

H.1 General

The assessment of geometrical imperfections shall be done by representative sample checks undertaken on the unloaded structure (except for self-weight) and, if possible, with the operational boundary conditions.

If the measurements of geometrical imperfections do not satisfy the geometrical tolerances stated in this annex any correction steps, such as by straightening, shall be investigated and decided individually.

H.2 Out-of-roundness tolerances

In case of circular closed shells, the out-of-roundness shall be assessed in terms of the parameter U_r (see Figure H.1) given by:

$$U_r = \frac{d_{\max} - d_{\min}}{d_{\text{nom}}}$$

where

$d_{\max}$ is the maximum measured internal diameter;

$d_{\min}$ is the minimum measured internal diameter;

d_{nom} is the nominal internal diameter.

The measured internal diameter from a given point shall be taken as the largest distance across the shell from the point to any other internal point at the same axial coordinate. An appropriate number of diameters shall be measured to identify the maximum and minimum values.

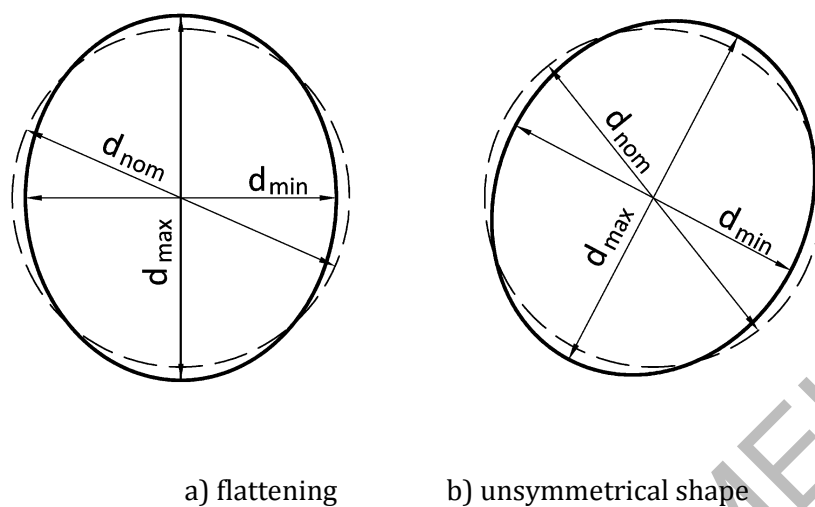


Figure H.1 — Measurement of diameters for assessment of out-of-roundness

The out-of-roundness parameter U_r shall satisfy the condition:

$$U_r \leq U_{r,\max}$$

where

$U_{r,\max}$ is the out-of-roundness tolerance parameter for the relevant execution tolerance class.

Values for the out-of-roundness tolerance parameter $U_{r,\max}$ are given in Table H.1.

Table H.1 — Values for out-of-roundness tolerance parameter $U_{r,\max}$

Tolerance class	Diameter range		
	$d \leq 0,5 \text{ m}$	$0,5 \text{ m} < d < 1,25 \text{ m}$	$d \geq 1,25 \text{ m}$
Class 1	0,030	$0,015 + 0,0200(1,25 - d)$	0,015
Class 2	0,020	$0,010 + 0,0133(1,25 - d)$	0,010
Class 3	0,014	$0,007 + 0,0090(1,25 - d)$	0,007
Class 4	0,010	$0,005 + 0,0067(1,25 - d)$	0,005

H.3 Non-intended eccentricity due to execution

At joints in shell walls perpendicular to membrane compressive forces, the non-intended eccentricity shall be evaluated from the measurable total eccentricity e_{tot} and the intended offset e_{int} from:

$$e_a = e_{\text{tot}} - e_{\text{int}}$$

where

e_a is the non-intended eccentricity due to misalignment between the middle surfaces of the joined plates, see Figure H.2 a);

- e_{tot} is the eccentricity between the middle surfaces of the joined plates, see Figure H.2 c);
- e_{int} is the intended offset between the middle surfaces of the joined plates, see Figure H.2 b).

The non-intended eccentricity e_a due to execution shall satisfy the maximum permitted non-intended eccentricity for the relevant execution tolerance class.

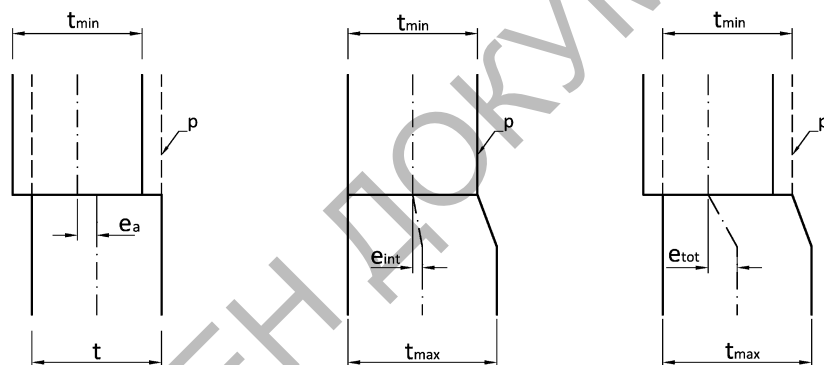
Values for the maximum eccentricity due to execution are given in Table H.2.

The non-intended eccentricity e_a shall also be assessed in terms of the non-intended eccentricity parameter U_e given by:

$$U_e = \frac{e_a}{t_{\text{ave}}}$$

where

t_{ave} is the mean thickness of the plates at the joint.



- a) non-intended eccentricity (execution tolerance) when there is no change of plate thickness
- b) intended offset at a change of thickness without non-intended eccentricity
- c) total eccentricity (non-intended plus intended) at change of thickness

Key

p perfect joint geometry

Figure H.2 — Non-intended eccentricity and intended offset at a joint

The non-intended eccentricity parameter U_e shall satisfy the condition:

$$U_e \leq U_{e,\text{max}}$$

where

$U_{e,\text{max}}$ is the non-intended eccentricity parameter for the relevant tolerance class.

Values for the maximum permitted non-intended eccentricity parameter $U_{e,\text{max}}$ are given in Table H.2.

Table H.2 — Values for maximum permitted non-intended eccentricities

Tolerance class	$U_{e,max}$	e_a
Class 1	0,30	$e_a \leq 4 \text{ mm}$
Class 2	0,20	$e_a \leq 3 \text{ mm}$
Class 3	0,14	$e_a \leq 2 \text{ mm}$
Class 4	0,10	$e_a \leq 1 \text{ mm}$

NOTE Intended offsets in shells with stepwise wall thickness and lapped joints are treated within EN 1999-1-5. They are not treated as geometrical imperfections.

H.4 Dent tolerances

A dent measurement gauge shall be used in every position (see Figure H.3) in both the meridional and circumferential directions. The meridional gauge shall be straight, but the gauge for measurements in the circumferential direction shall have a curvature equal to the nominal radius r of the middle surface of the shell. For spheres, the gauge for circumferential direction shall be used.

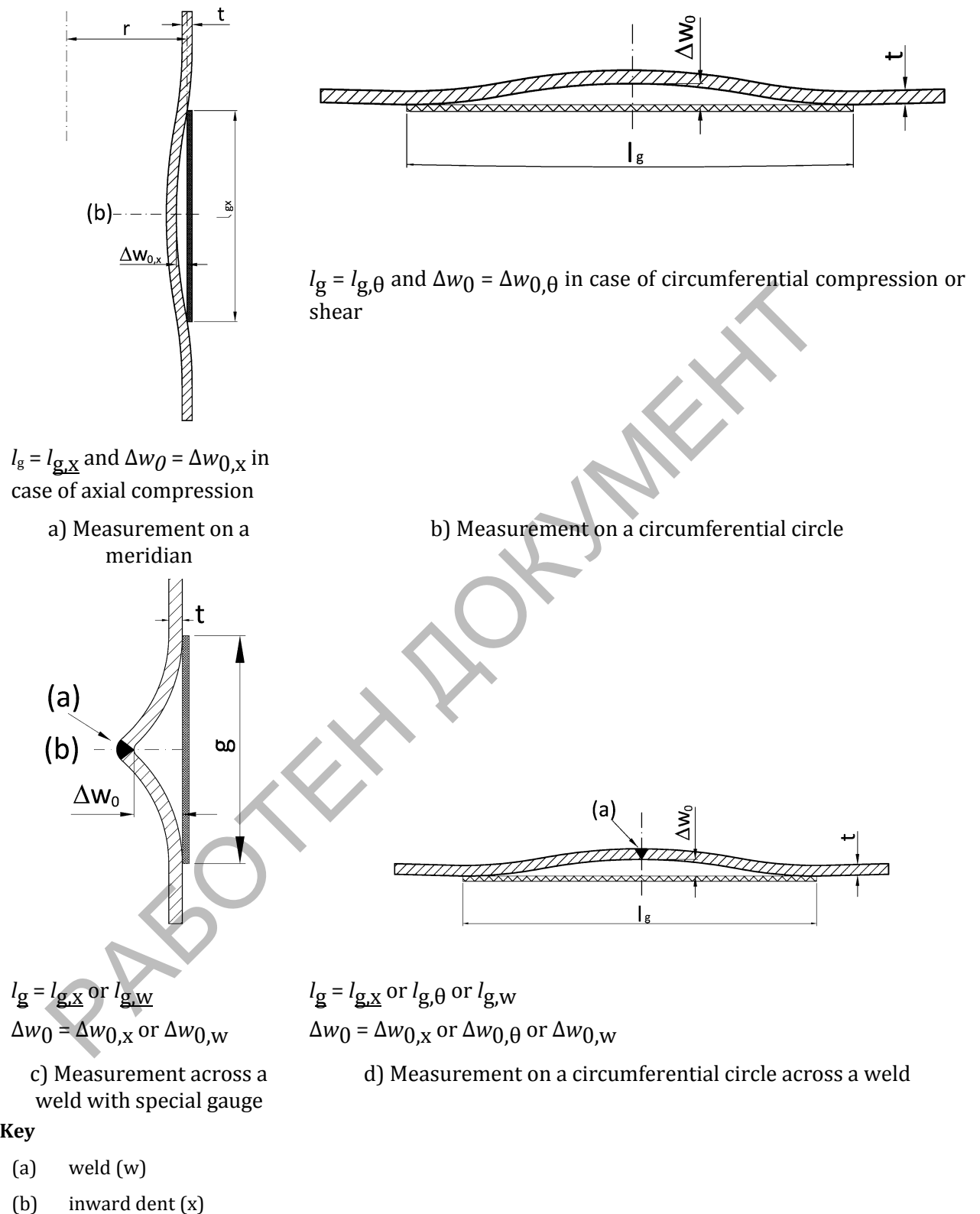


Figure H.3 — Measurement of depths Δw_0 of initial dents

The depth Δw_0 of initial dents in the shell wall shall be measured using gauges of length l_g according to Table H.3.

Table H.3 — Gauge length

Loading	Direction	Gauge length
Axial compression	Meridional and circumferential, including across welds	$l_{g,x} = 4\sqrt{rt}$
Circumferential compression or shear	Circumferential	$l_{g,\theta} = 2,3(l^2rt)^{0,25}$ but $l_{g,\theta} \leq r$ where l is the axial length of the shell segment
Any compression stresses	Across welds, both meridional and circumferential	$l_{g,w} = 25t$ or $l_{g,w} = 25t_{\min}$, but with $l_{g,w} \leq 500$ mm where $t_{\min}$ is the thickness of the thinnest plate at the weld

The depth of initial dents shall be assessed in terms of the dent parameters $U_{0,x}$, $U_{0,\theta}$ and $U_{0,w}$ given by:

$$U_{0,x} = \Delta w_{0,x} / l_{g,x} \quad U_{0,\theta} = \Delta w_{0,\theta} / l_{g,\theta} \quad U_{0,w} = \Delta w_{0,w} / l_{g,w}$$

The value of the dent parameters $U_{0,x}$, $U_{0,\theta}$ and $U_{0,w}$ shall satisfy the conditions:

$$U_{0,x} \leq U_{0,\max} \quad U_{0,\theta} \leq U_{0,\max} \quad U_{0,w} \leq U_{0,\max}$$

where

$U_{0,\max}$ is the dent tolerance parameter for the chosen tolerance class.

Values for the maximum permitted unintended eccentricity parameter $U_{0,\max}$ are given in Table H.4.

Table H.4 — Values for dent tolerance parameter $U_{0,\max}$

Tolerance class	Value of $U_{0,\max}$ for boundary conditions (BC)	
	BC1r, BC2r	BC1f, BC2f
Class 1	0,016	
Class 2	0,010	
Class 3	0,006	
Class 4	$\frac{1}{f_0} \left\{ 2,25\sqrt{\frac{t}{r}} + 0,01\sqrt{\frac{r}{t}} \right\}$ (f_0 in N/mm ²)	$\frac{1}{f_0} \left\{ 5\sqrt{\frac{t}{r}} + 0,02\sqrt{\frac{r}{t}} \right\}$ (f_0 in N/mm ²)

H.5 (f_0 in N/mm²) Interface flatness tolerances

If another structure continuously supports a shell (such as a foundation), its deviation from flatness at the interface shall not include a local slope in the circumferential direction greater than β_0 .

The value of β_0 is $\beta_0 = 0,1 \% = 0,001$ radians.

Annex I (informative)

Designation of requirements to welds on drawings

I.1 General

This annex gives guidelines on how to specify the requirements to welds and their testing in accordance with 12.4.3, 12.4.4.1 and 12.4.4.2. The information is normally given on drawings.

The following information should be given on the drawing(s), as relevant:

- The execution class should be designated as EXC1, EXC2, EXC3 or EXC4;
- The service category should be designated as SC1 (static) or SC2 (fatigue);
- Welding process;
- The extent of testing should be given in per cent and may be given in the following values: 5, 10, 20, 50 or 100;
- The quality levels should be given according to Annex K as D, C or B;
- For cases where additional quality requirements to the quality levels D, C and B are required in Annex K and defined in Tables 11, 12 and 13, these should be given as D+, C+ or B+;
- For cases where supplementary requirements are given in EN 1999-1-3 (see also Table K.4), they should be specified explicitly.

An overview for specifying the requirement for structures in SC2 is provided in Annex L.

I.2 Global specification

When the quality requirement can be specified globally, the following form of presentation of the quality requirements may be given on the drawings:

Table I.1 — Example 1

Quality and testing requirements:	
Execution class	EXC2
Service category	SC1
Welding process	MIG
Quality level acc. to EN ISO 10042:2005	C
Extent of NDT	10 %

NOTE This may often be the case for predominately static loaded structures.

I.3 Specific designations for welds, part of welds, details

The designation of the quality and inspection/testing requirements should be noted for each weld or detail according to EN ISO 2553 by adding a reference sign, QTR n (quality and testing requirements no. n) that contains information given in I.1.

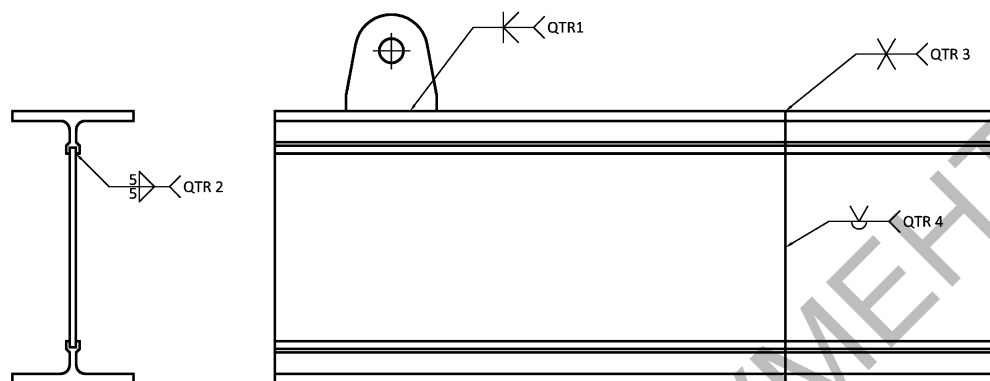


Figure I.1 — Example of designation on drawings

Table I.2 — Example for a QTR-requirement key

QTR-requirement	EXC	Service category	Welding process	Quality level for internal imperfections according to EN ISO 10042:2005 and EN 1090-3	Quality level for geometrical imperfections according to EN ISO 10042:2005	Supplementary requirement according to Annex L	Extent of NDT [%]
QTR 1	3	SC1	MIG	C	C	None	20
QTR 2	3	SC2	MIG	C	D	5.5	10
QTR 3	3	SC2	MIG	B	C	11.3	50
QTR 4	3	SC2	MIG	C	D	5.5	20

Annex J (informative)

Recommendations for description of site conditions and erection in the execution specification

J.1 Site conditions

Erection should not commence until the site for the construction works conforms to the requirements with respect to the safety of the works. The following items should be considered for preparation of the execution specification:

- a) provision and maintenance of hard standing for cranes and access equipment;
- b) access to the site and within the site;
- c) soil conditions affecting the safe operation of plant;
- d) possible settlement of supports to the structure during erection;
- 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 to the site and within the site should be given on a site plan showing width and clearance for access, 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 should be checked for consistency with those for other parts of the construction works. This check should consider such of the following items as are relevant:

- i) availability of site services and prearranged procedures for co-operation with other contractors;
- j) weights of structural components, equipment and storage loads allowed on the structure.

J.2 Erection method statement

An erection method statement should be prepared and it should be checked that the method conforms to the design assumptions, notably with regard to resistance of the partly erected structure to loads applied during construction.

NOTE 1 The erection method statement may deviate from the design basis method of erection, provided that it is a safe alternative.

This design basis method of erection should have considered such of the following items as are relevant:

- a) the position and types of site joints;
- b) the maximum piece size, weight and location;

- c) the sequence of erection;
- d) the stability concept for the part-erected structure including any requirements for temporary bracing or propping;
- e) conditions for removal of temporary bracing or propping, or any requirement for de-stressing or stressing the structure;
- f) features that would create a safety hazard during construction;
- g) timing and method for adjustment of foundation connections for bearings and or for grouting;
- h) camber and presets required including values to be checked at manufacturing stage;
- i) use of profiled sheeting to ensure stability;
- j) use of profiled sheeting to provide lateral restraint;
- k) the transportation of units, hoisting attachments;
- l) positions and conditions for supporting and jacking;
- m) the stability concept for the bearings;
- n) the deformations of the partly erected structure;
- o) expected settlements of the supports;
- p) particular positions and loads from cranes, stored material, counter weight, etc. for the various construction phases;
- q) instructions for the delivery, storage, lifting, building in and pre-tensioning of stayed cables;
- r) details for laying the wearing surface (sequence, temperature, laying speed);
- s) details of all temporary works and attachments to permanent works with instructions as to their removal.

Amendments to the erection method statement, including those necessitated by site conditions, should be checked and reviewed in accordance with this clause.

The erection method statement should describe procedures to be used to safely erect the aluminium structure and should take into account the technical requirements regarding the safety of the works.

NOTE 2 It is advised that the procedures link to specific work instructions.

The erection method statement should address all relevant items referred to above, and should consider in addition such of the following items as are relevant:

- i) experience from any trial erection documented in the report on trial assembly;
- ii) the restraints necessary to ensure stability prior to welding and to prevent local movement of the joint;
- iii) the lifting devices necessary;

- iv) the necessity to mark weights and/or centres of gravity on large or irregularly shaped pieces;
- v) the relationship between the weights to be lifted and the radius of operation where cranes are to be used;
- vi) the identification of sway forces, particularly those due to the forecast wind conditions on site during erection, and the exact methods of maintaining adequate sway resistance;
- vii) measures of coping with any safety hazards;
- viii) methods of providing safe access to positions of work and safe working positions.

РАБОТЕН ДОКУМЕНТ

Annex K (informative)

Guide for preparation of the execution specification for quality requirements of welds

K.1 General

This annex is intended to be used for preparation of the execution specification of the extent of testing and the quality requirements of welds. References and guidance for the items to be specified according to 12.4.3.1 are given below:

- **execution class**

The execution class is dependent on the consequence class, service category and production category. There might be national provisions which need to be observed;

- **service category and production category**

The service categories distinguish between quasistatic loaded components (SC1) and fatigue loaded components (SC2). The production categories distinguish between components and structures with bolted connections (PC1) and components and structures with welded connections (PC2);

- **quality level for welds according to EN ISO 10042**

Basis for the quality requirements for welds are the provisions in EN ISO 10042:2005, where the requirements are specified for three quality levels, designated B, C and D, where B gives the most stringent requirements. The requirements to quality level is dependent on execution class, service category and utilization grade as given in Tables K.4 and K.5;

- **additional quality requirements to the provisions of EN ISO 10042**

If for some types of imperfections the welds have a high utilization grade, the requirements are increased as compared to EN ISO 10042;

- **supplementary requirements to EN ISO 10042**

For welds in SC2, EN 1999-1-3 defines for some detail types supplementary requirements that are not listed in EN ISO 10042;

- **extent of additional non-destructive testing, NDT**

Additional NDT is inspection in addition to visual inspection. The requirements to additional NDT are given in Table K.2 for SC1 and Table K.3 for SC2. Visual inspection shall be carried out 100 % for all welds;

- **any additional tests and testing methods**

In case additional tests are required, the test methods and the acceptance criteria shall be specified.

K.2 Utilization grades and utilization ranges

K.2.1 General

Utilization grades express the level of the design action effect as compared to the design resistance of the weld. It is used as a parameter to determine the extent of testing and the acceptance criteria for welds.

This European Standard specifies three ranges for the utilization grade, denoted UR1, UR2 and UR3, called utilization ranges, see Table K.1.

Table K.1 — Utilization ranges

Service Category	Loading	UR1	UR2	UR3
SC1	Predominantly static	$U \leq 0,30$	$0,30 < U \leq 0,60$	$0,60 < U \leq 1,0$
SC2	Fatigue	$U \leq 0,30$	$0,30 < U \leq 0,60$	$0,60 < U$
	Fatigue U, if damage assessment D_L according to EN 1999-1-3	$U \leq 0,30$	$0,30 < U \leq 0,70$	$0,70 < U$

K.2.2 Utilization grade for components and structures in service category SC1

Rules for determination of the utilization grade U are given in EN 1999-1-1.

K.2.3 Utilization grade for components and structures in service category SC2

Rules for determination of the utilization grade U are given in EN 1999-1-3.

K.3 Extent of additional NDT

K.3.1 Extent of NDT (%) for components/structures in service category SC1

The extent of NDT (in %) should be specified to be not less than according to the provisions of Table K.2.

Table K.2 — Extent of additional NDT (in %) for structures/components in service category SC1

Type of weld	Utilization ranges	EXC1	EXC2	EXC3	EXC4
Butt welds under transverse tension and shear	UR3	-	10	20	To be specified, but not less than for EXC3
	UR2	-	-	10	
All other welds	UR3	-	5 ^a	10	
	UR2	-	-	5	

^a No NDT for connections under pure compression

K.3.2 Extent of additional NDT (%) for components/structures in service category SC2

The extent of NDT (in %) should be specified to be not less than according to the provisions of Table K.3.

Table K.3 — Extent of additional NDT (%) for components/structures in service category SC2

Type of weld	Utilization ranges	EXC1	EXC2	EXC3	EXC4
Butt welds ^a (each QL) and fillet welds QL B ^b both under tension ^c or shear excl. DT 3.5 and 3.6 in EN 1999-1-3:2007, Table J3	UR3	-	20	50	100
	UR2	-	10	20	50
Fillet welds under tension or shear	UR3	-	10	20	50
	UR2	-	5	10	20
All other welds	UR3	-	5	10	10
	UR2	-	-	5	5
^a Butt weld with partial penetration (see EN 1999-1-3 for the relevant detail type DT) are basically not allowed for fatigue, see EN 1999-1-1. ^b This concerns only fillet welds, where EN 1999-1-3 specifies quality level B for internal imperfections. ^c Includes longitudinal welds that are subject to the strain of adjacent member.					

K.4 Extent of destructive testing for friction stir welds

The extent of testing of friction stir welds should be specified to be not less than according to the provisions of Table K.4.

When the product is provided by a sub-contractor, it shall be documented that the product has been tested in accordance with Table K.4.

Table K.4 — Extent of testing of friction stir welds

Type of weld	Utilization ranges	EXC1	EXC2	EXC3	EXC4
FSW	All	-	Start or end of every 10th weld	Start or end of every 5th weld	To be specified

K.5 Acceptance criteria for welds

K.5.1 Acceptance criteria for welds in service category SC1

If no special conditions are given, the quality level should be specified according to the provisions of Table K.5.

Table K.5 — Quality level for welds for structures/components in service category SC1

Utilization ranges	Quality level in accordance with EN ISO 10042:2005 ^{a b c}
UR1	D
UR2	D
UR3	C
^a For the imperfections 2.7 and 2.9 according EN ISO 10042:2005, the requirements apply when the weld length is more than 25 mm. For shorter weld lengths, these imperfections are not permitted. ^b The requirements for the following imperfections according to EN ISO 10042:2005 do not apply: 1.4, 1.11, 1.12, 1.14, 1.15, 1.17, 2.2 and 2.5. ^c Additional requirements to EN ISO 10042:2005 are given in Table 10.	

K.5.2 Acceptance criteria for welds in service category SC2**K.5.2.1 Detail types according to EN 1999-1-3**

If no special conditions are given, the quality level should be specified according to the provisions of Table K.6. When additional requirements (B+, C+ or D+) are specified, load direction and the difference between geometrical and internal imperfections should be considered. The guidelines given in Annex L may be used.

Table K.6 — Quality level for welds for structures/components in service category SC2

Utilization ranges	Quality level according to EN ISO 10042:2005	Additional requirements to be specified	Supplementary ^a requirements to be specified
UR1	See recommendations for SC1 in Table K.4.		
UR2	See EN 1999-1-3:2007, Annex J	None	See EN 1999-1-3:2007, Annex J
UR3	See EN 1999-1-3:2007, Annex J	B+, C+ or D+ respectively, depending on detail type ^b	See EN 1999-1-3:2007, Annex J
^a The supplementary requirements are defined for the concerned detail types in EN 1999-1-3:2007, Annex J. ^b Guideline is given in Annex L.			

K.5.2.2 Other detail types

For detail types not listed in EN 1999-1-3, if the fatigue capacity is based on tests or if weld details deviate from the detail description in EN 1999-1-3, the quality level may be defined corresponding to provisions in EN 1999-1-3.

In doubt the quality level B should be applied. For the service category SC2 and the range of utilization grade UR3, the additional quality requirements B+ also apply (see Annex L).

Annex L (informative)

Guide for specification of quality requirements for components and structures in SC2

This annex is intended to be used for specification of the quality requirements of welds for components and structures in SC2.

Table L.1 includes the required quality levels according to EN ISO 10042:2005, the supplementary requirements defined in EN 1999-1-3 for the detail types listed in EN 1999-1-3:2007, Annex J, and guidelines for the specification of additional requirements given in Table 11, 12 and 13 (B+, C+ and D+).

Table L.1 — Guide for specification of requirements for welds for components and structures in -SC2

Detail type EN 1999-1-3:2007	Quality and execution requirements			
	Utilization ranges		Deviating provisions for surface and geometrical imperfections according to EN 1999-1-3	Supplementary requirements according to EN 1999-1-3 to be given in the execution specification
	UR2	UR3		
3.1	C	C	-	Grind undercut smooth
3.2	C	C		
3.3	C	C		
3.4	C	C		
3.5	C	C		
3.6	C	C	-	Grind radius parallel to stress direction. Weld toe shall be fully ground out.
3.7	C	C		
3.8	C	C		
5.1	B	B+	C	Continuous automatic welding.
5.2	C	C	-	-
5.3	C	C	D+	Any backing bar to be continuous. Discontinuity in direction of longitudinal weld shall not be higher than 1/10 of plate thickness or exceed a slope steeper than 1:4.

Detail type EN 1999-1-3:2007	Quality and execution requirements			
	Utilization ranges		Deviating provisions for surface and geometrical imperfections according to EN 1999-1-3	Supplementary requirements according to EN 1999-1-3 to be given in the execution specification
	UR2	UR3		
5.4	B	B	C	Discontinuity in direction of longitudinal weld shall not be higher than 1/10 of plate thickness or exceed a slope steeper than 1:4.
5.5	C	C	D+	Discontinuity in direction of longitudinal weld shall not be higher than 1/10 of plate thickness or exceed a slope steeper than 1:4.
5.6	C	C	D+	-
5.7	C	C	D+	-
7.1.1	B	B+	-	Root ground off; extension plates used on ends, cut off and ground flush in direction of stress.
7.1.2	C	C+	-	Root ground off; extension plates used on ends, cut off and ground flush in direction of stress.
7.2.1	B	B+	-	Root ground off; extension plates used on ends, cut off and ground flush in direction of stress; overfill angle $\geq 150^\circ$. Normally it is only feasible to keep the requirement " $\geq 150^\circ$ " with a plate thickness ≥ 10 mm.
7.2.2	B	B+	C and C+.	Root ground off; extension plates used on ends, cut off and ground flush in direction of stress.

Detail type EN 1999-1- 3:2007	Quality and execution requirements			
	Utilization ranges		Deviating provisions for surface and geometrical imperfections according to EN 1999- 1-3	Supplementary requirements according to EN 1999-1- 3 to be given in the execution specification
	UR2	UR3		
7.2.3	C	C+	-	Root ground off; extension plates used on ends, cut off and ground flush in direction of stress.
7.3.1	C	C+	-	Extension plates used on ends, cut off and ground flush in direction of stress.
7.3.2	C	C+	-	Extension plates used on ends, cut off and ground flush in direction of stress.
7.4.1	B	B+	-	Extension plates used on ends, cut off and ground flush in direction of stress; overfill angle $\geq 150^\circ$. Normally it is only feasible to keep the requirement " $\geq 150^\circ$ " with a plate thickness ≥ 10 mm.
7.4.2	C	C+	-	Extension plates used on ends, cut off and ground flush in direction of stress.
7.4.3	C	C+	-	Extension plates used on ends, cut off and ground flush in direction of stress.
7.5	D	D	-	Extension plates used on ends, cut off and ground flush in direction of stress; seams with partial penetration are not allowed for joints significantly fatigue loaded.

Detail type EN 1999-1-3:2007	Quality and execution requirements			
	Utilization ranges		Deviating provisions for surface and geometrical imperfections according to EN 1999-1-3	Supplementary requirements according to EN 1999-1-3 to be given in the execution specification
	UR2	UR3		
7.6	B	B+	-	Extension plates used on ends, cut off and ground flush in direction of stress.
9.1	C	C+	-	Extension plates used on ends, cut off and ground flush in direction of stress.
9.2	C	C+	-	Extension plates used on ends, cut off and ground flush in direction of stress.
9.3	C	C+	-	Extension plates used on ends, cut off and ground flush in direction of stress.
9.4	C	C+	-	
9.5	C	C+	-	
9.6	C	C+	-	
11.1	B	B+	-	Root ground off Extension plates used on ends, cut off and ground flush in direction of stress.
11.2	B	B+	-	Extension plates used on ends, cut off and ground flush in direction of stress.
11.3	B	B+	C	Root ground off Extension plates used on ends, cut off and ground flush in direction of stress. Overfill angle $\geq 150^\circ$. Normally it is only feasible to keep the requirement " $\geq 150^\circ$ " with a plate thickness ≥ 10 mm.

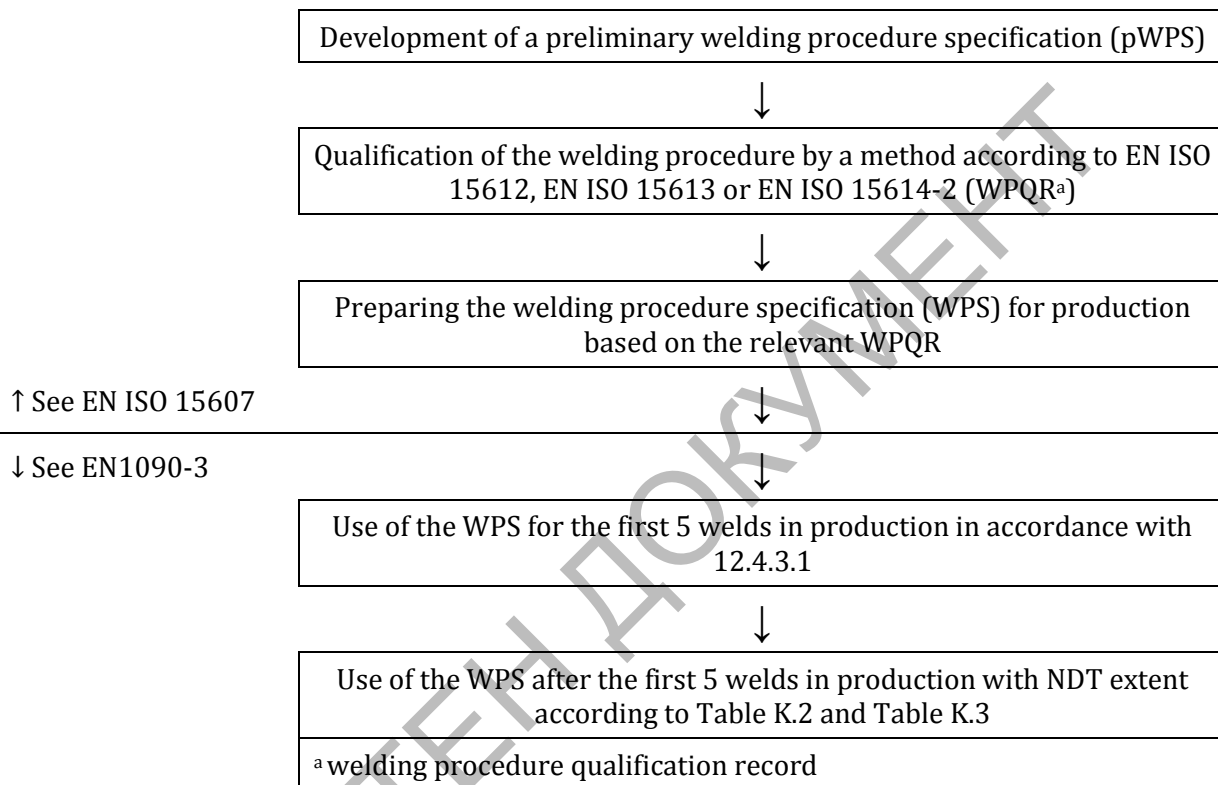
Detail type EN 1999-1- 3:2007	Quality and execution requirements			
	Utilization ranges		Deviating provisions for surface and geometrical imperfections according to EN 1999- 1-3	Supplementary requirements according to EN 1999-1- 3 to be given in the execution specification
	UR2	UR3		
11.4	C	C	-	Extension plates used on ends, cut off and ground flush in direction of stress.
13.1	C	C	-	-
13.2	C	C	-	Welded on all sides
13.3	C	C	-	-
13.4	C	C+	C	-
13.5	C	C	-	Welded on all sides

Annex M

(informative)

Chart for development and use of a welding procedure specification (WPS)

Table M.1 — Guide for development and use of a welding procedure specification



Annex N (informative)

Weld studs connected by arc stud welding with tip ignition

N.1 Introduction

(1) This informative annex contains provisions both for design and execution. The design provisions are necessary for the design of tip ignition welded studs, but are not included in EN 1999-1-1:2007. The design provisions are intended to be transferred to EN 1999-1-1 at its next revision which should then take precedence over the design provisions of this annex. In the next revision of this standard, the design provisions in this annex are then intended to be deleted.

N.2 Area of application

(1) This annex applies to weld studs on load-bearing structures and building components in execution classes EXC1 and EXC2 under predominantly static loading, as long as the screwed connections with the weld studs are not scheduled to be repeatedly untightened and tightened (e.g. in temporary structures).

(2) The materials given in Table N.1 in the tempers stated in EN 1999-1-1 and EN 1999-1-4 are suitable as a base material onto which the weld studs may be welded.

Table N.1 — Base material onto which the weld studs may be welded

EN AW-3004(AlMn1Mg1)	EN AW-5005/5005A(AlMg1)	EN AW-6060(AlMgSi)
EN AW-3005(AlMn1Mg0,5)	EN AW-5049(AlMg2Mn0,8)	EN AW-6063(AlMg0,7Si)
EN AW-3103(AlMn1)	EN AW-5052(AlMg2,5)	
EN AW-3105(AlMn0,5Mg0,5) ^a	EN AW-5251(AlMg2) ^a	
	EN AW-5454(AlMg3Mn)	
	EN AW-5754(AlMg3)	
^a Material listed only in EN 1999-1-4.		

(3) Weld studs with tip ignition type PT made from EN AW-5754(AlMg3) H12 and EN AW-1050A(Al99,5) H14 with normal diameter d_b (corresponding to d_1 in accordance with EN ISO 13918) of 4 mm to 6 mm are suitable. For weld studs made from EN AW-5754, which are welded onto EN AW-5050 and EN AW-6063, the nominal diameter d_b is restricted to 5 mm.

(4) The weld studs shall correspond to EN ISO 13918 in conjunction with an inspection certificate 2.1 in accordance with EN 10204.

N.3 Construction

(1) The connections shall be designed so that the weld studs are not intended to be subjected to bending stress.

(2) If the holes for the weld studs exceed the hole tolerance of EN 1999-1-1 for bolted connections (as a rule), the following applies:

Only a statically determinate system may be used for transferring in-plane forces when verifying the limit state of the structural load-bearing capacity, i.e. the number of weld bolts used for the transfer of

forces shall not be greater than the number of conditions of equilibrium to be fulfilled, unless other means (e.g. design measures) are used to ensure that in the limit state, which is achieved by means of in-plane rigid body motion, the tolerance (distance between the weld stud and the hole edge) for all the weld studs used for load transfer is less than 1 mm.

For long slotted holes the bearing may be calculated in accordance with the EN 1999-1-1 regulations if:

- i) The hole is completely covered by lateral support and
- ii) the regulations of EN 1090-3:2017, 8.2.1, paragraph 6 have been observed and
- iii) the maximum dimensions of the hole are no greater than 2,5 times the weld stud diameter.

(3) In many cases controlled tightening of the nuts on the weld studs is necessary for various reasons (risk of overtightening, benefits of pretensioning).

N.4 Design

(1) For the design of the welded joint, HAZ in its standard sense and extent does not need to be taken into account due to the low energy input. Only a narrow zone in the weld transition area between the weld stud and the base material is affected by heat.

(2) The values in Table N.2 are to be used as characteristic values for the design of the bolt material not affected by heat.

Table N.2 — Characteristic values of the weld stud material not affected by heat

Material/temper	EN AW-5754(AlMg3) H12	EN AW-1050A(Al99,5) H14
f_{ub}	230 N/mm ²	100 N/mm ²

(3) The characteristic values F_{tb}, R_k of the tensile forces which can be transferred through the fusion zone are given in Table N.3. These values shall be verified by a welding procedure qualification test, whereby specific minimum values for the average breaking load shall be demonstrated and a maximum value for the coefficient of variation shall not be exceeded. The design value F_{tb}, R_d is derived from F_{tb}, R_k to $F_{tb}, R_d = k_2 F_{tb}, R_k / \gamma_2$ with the safety factor γ_2 and k_2 for aluminium bolts in accordance with EN 1999-1-1:2007, Table 8.5, Formula (8.17).

Table N.3 — Characteristic values of F_{tb}, R_k of the tensile forces which can be transferred through the fusion zone

F_{tb}, R_k	Weld stud diameter 4 mm	Weld stud diameter 5 mm	Weld stud diameter 6 mm
EN AW-5754 H12	1680 N	2710 N	3840 N
EN AW-1050 H14	800 N	1300 N	1840 N

(4) For the load-bearing capacity of the fusion zone exposed to shear stress, the smaller $f_{u, haz}$ value of the mating of materials between the stud/base material applies. Refer to Table 3.2a or Table 3.2b of EN 1999-1-1:2007 for the $f_{u, haz}$ value for the base material. The values in Table N.4 apply for the $f_{ub, haz}$ value of the bolt. If no $f_{u, haz}$ values can be found in EN 1999-1-1:2007, Table 3.2 for the alloys or tempers listed in EN 1999-1-4, the strength value of temper O (soft) is to be used for $f_{u, haz}$ – see EN 485-2.

Table N.4 — $f_{ub,haz}$ value of weld stud

Material/temper	EN AW-5754(AlMg3) H12	EN AW-1050A(Al99,5) H14
$f_{ub,haz}$	180 N/mm ²	60 N/mm ²

The design value $F_{v,Rd}$ of the shear force is derived in accordance with the Formula (8.9) of EN 1999-1-1:2007 from the decisive $f_{u,haz}$ value and the weld stud area $A = (\pi/4) d_b^2$.

(5) In the fusion zone, the load-bearing capacity is verified if condition (N.1) has been met.

$$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{F_{tb,Rd}} \leq 1 \quad (N.1)$$

(6) The verification of the load bearing capacity of the weld stud subjected to tension and shear has to be in accordance with condition (8.20) and Formulae (8.9) and (8.17) of EN 1999-1-1:2007. For this, f_{ub} according to Table N.2 shall be used as a characteristic value and the coefficients for aluminium bolts apply.

(7) When calculating the load-bearing capacity $B_{p,Rd}$ of the base material for punching shear caused by forces in the direction of the bolt axis, the nominal diameter d_b of the bolt shall be used instead of d_m in Formula (8.19) of EN 1999-1-1:2007.

(8) The verifications required under (5) to (7) do not replace proofs of serviceability. If serviceability, e.g. in façades, may be impaired by local, plastic deformations of the base material (interference of the visually perceptible appearance), serviceability shall be assessed in individual cases from experience or on the basis of tests.

(9) For the building component to which the weld studs are connected (base material), all other verifications of load-bearing capacity required in accordance with EN 1999-1-1 shall be carried out.

N.5 Qualification of the welding procedure

(1) The welding procedure and the welder shall be qualified for the welding process in accordance with EN ISO 14555.

(2) As a deviation from and a supplement to EN ISO 14555:2014, the following applies:

a) The tests specified in EN ISO 14555 shall have been successfully performed for each stud welding device, method (contact welding, gap welding), and each mating of weld bolt, material and temper of the base material, and there shall be a corresponding welding procedure specification. For the welding procedure qualification test, the thickness of the base material shall be selected so that a punching through does not occur. Qualification for one sheet thickness provides qualification for all smaller sheet thicknesses. The information required for a welding procedure specification may also be determined based on parameters from existing welding procedure specifications if this can occur by means of interpolation.

b) The regulations of EN ISO 14555:2014, Annex A shall be followed.

c) For the tensile strength test, a total of 21 weld studs shall be welded and tested during the welding procedure qualification test (deviating from EN ISO 14555:2014, Table 3).

— If the tensile test is carried out with measurement of the force, the coefficient of variation shall not exceed the limit value given in Table N.5 for the totality of the breaking loads and the average value shall be above the minimum value given in Table N.5. Furthermore, for at least half of the tested weld studs the rupture shall occur in the weld stud.

- If the tensile test is carried out without measurement of the breaking load, e.g. in accordance with EN ISO 14555:2014, Fig. 4, the location of the rupture shall be in the weld stud for all the samples. A rupture in the welded joint or stripping of the thread is not permissible.

For the bending test according to EN ISO 14555:2014, 10 studs (the number deviating from Table 3 of EN ISO 14555:2014) shall be welded and tested in a bending test for the welding procedure test. A rupture in the fusion zone shall not occur in any of the 10 samples.

Table N.5 — Limit value for coefficients of variation and average values

	Max coefficient of variation	Weld stud diameter 4 mm	Weld stud diameter 5 mm	Weld stud diameter 6 mm
EN AW-5754 H12	0,10	2020 N	3260 N	4620 N
EN AW-1050 H14	0,05	880 N	1420 N	2010 N

(3) If there is no base material available (same alloy and same temper as in the application example) for the welding procedure test which is thick enough to prevent punching shear, the proof of sufficient bearing capacity in tension shall be verified as follows: The value of tensile force measured during punching shear shall not be lower than the $B_{p,R}$ value according to Formula (N.2) for any of the 10 samples.

$$B_{p,R} = 0,6\pi d_b t_p f_u \quad (\text{N.2})$$

For this, d_b is the weld stud diameter, t_p is the thickness of the base material on which the stud is welded, and f_u is the strength of the base material which depends on the material and its temper according to Table 3.2a or Table 3.2b of EN 1999-1-1:2007 or according to Table 3.1 of EN 1999-1-4:2007.

In a limit case with a configuration (depending on geometry and strength) where with the welding procedure test in tension the rupture is punching shear in some cases and failure in the weld stud or the fusion zone in the other cases then the breaking of the weld stud or the fusion zone shall not be below the characteristic value $F_{tb,Rk}$ according to Table N.3. Furthermore, in the cases with failures in the weld stud or the fusion zone this failure shall have occurred with at least 50 % of these cases in the weld stud.

Also for the case in question according to EN ISO 14555:2014, Table 3, 10 weld studs shall be welded for the welding procedure test. A rupture in the fusion zone shall not occur in any of the 10 samples.

(4) During production, simplified production tests (minimum of 3) with a visual inspection and bending test in accordance with EN ISO 14555:2014, Clause 12 shall be carried out:

- at the start of work for every shift
- if there is a change in the power source/ welding machine/equipment
- if there is a change to the welding procedure specification (WPS)

(5) The specifications of EN 1090-3 also apply. However, the following are not required:

- Non-destructive tests, apart from the visual inspection
- The regulations in EN 1090-3:2017, 12.4.3.2, paragraph 3, Point b) 1)

Bibliography

- [1] FprEN 1090-5, *Execution of steel structures and aluminium structures — Part 5: Technical requirements for thin-gauge, cold-formed aluminium elements and structures for roof, ceiling, floor and wall applications*
- [2] EN 1396, *Aluminium and aluminium alloys — Coil coated sheet and strip for general applications - Specifications*
- [3] EN 12206-1, *Paints and varnishes — Coating of aluminium and aluminium alloys for architectural purposes — Part 1: Coatings prepared from coating powder*
- [4] EN 12487, *Corrosion protection of metals — Rinsed and non-rinsed chromate conversion coatings on aluminium and aluminium alloys*
- [5] EN ISO 2320, *Fasteners — Prevailing torque steel nuts — Functional properties (ISO 2320)*
- [6] EN ISO 2553, *Welding and allied processes — Symbolic representation on drawings — Welded joints (ISO 2553)*
- [7] EN ISO 7040, *Prevailing torque type hexagon regular nuts (with non-metallic insert) — Property classes 5, 8 and 10 (ISO 7040)*
- [8] EN ISO 7042, *Prevailing torque type all-metal hexagon high nuts — Property classes 5, 8, 10 and 12 (ISO 7042)*
- [9] EN ISO 7599, *Anodizing of aluminium and its alloys — General specifications for anodic oxidation coatings on aluminium (ISO 7599)*
- [10] EN ISO 7719, *Prevailing torque type all-metal hexagon regular nuts — Property classes 5, 8 and 10 (ISO 7719)*
- [11] EN ISO 9000, *Quality management systems — Fundamentals and vocabulary (ISO 9000)*
- [12] EN ISO 10511, *Prevailing torque type hexagon thin nuts (with non-metallic insert) (ISO 10511)*
- [13] EN ISO 10512, *Prevailing torque type hexagon regular nuts (with non-metallic insert) with metric fine pitch thread — Property classes 6, 8 and 10 (ISO 10512)*
- [14] EN ISO 10513, *Prevailing torque type all-metal hexagon high nuts with metric fine pitch thread — Property classes 8, 10 and 12 (ISO 10513)*
- [15] EN ISO 15481, *Cross recessed pan head drilling screws with tapping screw thread (ISO 15481)*
- [16] EN ISO 15973, *Closed end blind rivets with break pull mandrel and protruding head — AIA/St (ISO 15973)*
- [17] EN ISO 15974, *Closed end blind rivets with break pull mandrel and countersunk head — AIA/St (ISO 15974)*
- [18] EN ISO 15977, *Open end blind rivets with break pull mandrel and protruding head — AIA/St (ISO 15977)*

- [19] EN ISO 15978, *Open end blind rivets with break pull mandrel and countersunk head — AIA/St (ISO 15978)*
- [20] EN ISO 15981, *Open end blind rivets with break pull mandrel and protruding head — AIA/AIA (ISO 15981)*
- [21] EN ISO 17663, *Welding — Quality requirements for heat treatment in connection with welding and allied processes (ISO 17663)*
- [22] *Aluminium-Trapezprofile und ihre Verbindungen*. GDA, Gesamtverband der Aluminiumindustrie, Düsseldorf, 2006
- [23] GSB AL 631, *International Quality Regulations For The Coating of Building Components*, GSB International, Düsseldorf, www.gsb-international.de
- [24] Qualanod, *Specifications for the QUALANOD Quality Label for Sulphuric Acid-Based Anodizing of Aluminium*, Qualanod, Zurich, www.qualanod.net
- [25] Qualicoat, *Specifications for a quality label for liquid and powder coatings on aluminium for architectural applications*, Qualicoat, Zurich, www.qualicoat.net