



BSI Standards Publication

Eurocode 3 — Design of steel structures

Part 1-8: Joints

National foreword

This British Standard is the UK implementation of EN 1993-1-8:2024. It supersedes BS EN 1993-1-8:2005, which will be withdrawn on 30 March 2028.

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

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

National choice is allowed in this standard where explicitly stated within notes. The National Annex to this standard contains the national choices to be used for buildings and civil engineering works constructed in the UK.

The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010. This document forms part of the second generation of EN Eurocodes.

The second generation of EN Eurocodes is expected to be published between 2023 and 2026. These documents are being published as soon as they are available. This is being done to enable users to prepare for the transition from the first generation to second generation of EN Eurocodes.

UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028. Until that date, the first generation documents should be considered as the applicable standards for buildings and civil engineering works constructed in the UK unless otherwise specified by the relevant authority or in the specification for a particular project.

This standard is intended to be used with its National Annex and other referenced documents, including other second generation Eurocodes, as an interdependent suite of documents.

While the use of provisions in this standard in conjunction with first generation Eurocodes is not precluded, it should be undertaken with care and should only be done when users are satisfied that it will not result in a lower level of reliability than the minimum level set in the first generation Eurocodes and associated UK National Annexes.

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Date

Text affected

English Version

Eurocode 3 - Design of steel structures - Part 1-8: Joints

Eurocode 3 - Calcul des structures en acier - Partie 1-8 :
Assemblages

Eurocode 3 - Bemessung und Konstruktion von
Stahlbauten - Teil 1-8: Anschlüsse

This European Standard was approved by CEN on 1 January 2024.

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European foreword

This document (EN 1993-1-8:2024) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2027 and conflicting national standards shall be withdrawn at the latest by March 2028.

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

This document supersedes EN 1993-1-8:2005 and its amendments and corrigenda.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

The main changes compared to the previous edition are listed below:

- the Scope was extended to steel grades up to S700;
- the Scope was extended to the design of nominally pinned connections;
- new provisions for the design and fabrication of connections with bolts in threaded holes;
- new provisions for the design of butt welds in steel grades higher than S460;
- new provisions for the design of column bases with fasteners between steel and concrete;
- revision of the Table of contents, with four Normative Annexes (A-D) summarizing (A) the structural properties of basic components; (B) provisions for the design of moment-resisting beam-to-column joints and splices; (C) provisions for the design of nominally pinned connections (new); and (D) provisions for the design of column bases;
- a non-linear model to calculate the deformation of the bolt hole due to bearing of fasteners against the plate was introduced, including a revised formulation for the design value of bearing resistance;
- revision of the requirements for the design of a group of fasteners in bearing-type connections;
- an alternative method for the verification of the design resistance of welds explicitly accounting for the filler material properties was introduced;
- revision of the requirements for the design of pins;
- revision of the requirements for the evaluation of the design resistance and stiffness coefficients of the component “column web panel in shear”;
- revision and clarification of the design tables for hollow section joints.

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

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

0 Introduction

0.1 Introduction to the Eurocodes

The Structural Eurocodes comprise the following standards generally consisting of a number of Parts:

- EN 1990, *Eurocode: Basis of structural and geotechnical design*
- EN 1991, *Eurocode 1: Actions on structures*
- EN 1992, *Eurocode 2: Design of concrete structures*
- EN 1993, *Eurocode 3: Design of steel structures*
- EN 1994, *Eurocode 4: Design of composite steel and concrete structures*
- EN 1995, *Eurocode 5: Design of timber structures*
- EN 1996, *Eurocode 6: Design of masonry structures*
- EN 1997, *Eurocode 7: Geotechnical design*
- EN 1998, *Eurocode 8: Design of structures for earthquake resistance*
- EN 1999, *Eurocode 9: Design of aluminium structures*
- New parts are under development, e.g. Eurocode for design of structural glass.

0.2 Introduction to EN 1993

EN 1993 (all parts) applies to the design of buildings and civil engineering works in steel. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design and verification that are given in EN 1990 — Basis of structural and geotechnical design.

EN 1993 (all parts) is concerned only with requirements for resistance, serviceability, durability and fire resistance of steel structures. Other requirements, e.g. concerning thermal or sound insulation, are not covered.

EN 1993 is subdivided in various parts:

EN 1993-1, *Design of Steel Structures — Part 1: General rules and rules for buildings;*

EN 1993-2, *Design of Steel Structures — Part 2: Bridges;*

EN 1993-3, *Design of Steel Structures — Part 3: Towers, masts and chimneys;*

EN 1993-4, *Design of Steel Structures — Part 4: Silos and tanks;*

EN 1993-5, *Design of Steel Structures — Part 5: Piling;*

EN 1993-6, *Design of Steel Structures — Part 6: Crane supporting structures;*

EN 1993-7, *Design of Steel Structures — Part 7: Sandwich panels.*

EN 1993-1 in itself does not exist as a physical document, but comprises the following 14 separate parts, the basic part being EN 1993-1-1:

EN 1993-1-1, *Design of Steel Structures — Part 1-1: General rules and rules for buildings;*

EN 1993-1-2, *Design of Steel Structures — Part 1-2: Structural fire design;*

EN 1993-1-3, *Design of Steel Structures — Part 1-3: Cold-formed members and sheeting*;

NOTE Cold-formed welded hollow sections supplied according to EN 10219 (all parts) are covered in EN 1993-1-1.

EN 1993-1-4, *Design of Steel Structures — Part 1-4: Stainless steel structures*;

EN 1993-1-5, *Design of Steel Structures — Part 1-5: Plated structural elements*;

EN 1993-1-6, *Design of Steel Structures — Part 1-6: Strength and stability of shell structures*;

EN 1993-1-7, *Design of Steel Structures — Part 1-7: Plate assemblies with elements under transverse loads*;

EN 1993-1-8, *Design of Steel Structures — Part 1-8: Joints*;

EN 1993-1-9, *Design of Steel Structures — Part 1-9: Fatigue*;

EN 1993-1-10, *Design of Steel Structures — Part 1-10: Material toughness and through-thickness properties*;

EN 1993-1-11, *Design of Steel Structures — Part 1-11: Tension components*;

EN 1993-1-12, *Design of Steel Structures — Part 1-12: Additional rules for steel grades up to S960*;

EN 1993-1-13, *Design of Steel Structures — Part 1-13: Beams with large web openings*;

EN 1993-1-14, *Design of Steel Structures — Part 1-14: Design assisted by finite element analysis*.

All parts numbered EN 1993-1-2 to EN 1993-1-14 treat general topics that are independent from the structural type like structural fire design, cold-formed members and sheeting, stainless steel structures, plated structural elements, etc.

All parts numbered EN 1993-2 to EN 1993-7 treat topics relevant for a specific structural type like steel bridges, towers, masts and chimneys, silos and tanks, piling, crane supporting structures, etc. EN 1993-2 to EN 1993-7 refer to the generic rules in EN 1993-1 and supplement, modify or supersede them.

0.3 Introduction to EN 1993-1-8

EN 1993-1-8 gives rules for the design of joints in steel structures. It includes rules for resistance, stiffness, and deformation capacity of components and recommendations for the properties to be used in analyses. It assumes that the execution of its provisions follows the requirements given in EN 1090-2.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National Annex for EN 1993-1-8

National choice is allowed in this document where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing EN 1993-1-8 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this document is to be used.

When no national choice is made and no default is given in this document, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

National choice is allowed in EN 1993-1-8 through notes to the following clauses:

4.2(4)	4.3.1(2)	4.3.2(1)	5.1.1(3)
5.2(1)	5.9.3(1)	5.9.3(3)	6.2(3)
7.3.1(1)	9.1(5)	9.1(5)	A.17.1(2)
B.3.2.2(9)	C.2(5)		

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of EN 1993-1-8

(1) EN 1993-1-8 provides rules for structural design of joints subject to predominantly static loading using all steel grades from S235 up to and including S700, unless otherwise stated in individual clauses.

NOTE As an alternative to the design rules provided in Clause 9, the design rules given in CEN/TS 1993-1-801¹ “Eurocode 3: Design of steel structures — Part 1-801: Hollow section joints design according to the component method” can be used.

(2) The provisions in this document apply to steels complying with the requirements given in EN 1993-1-1 and to material thickness greater than or equal to 3 mm, unless otherwise stated in individual clauses.

1.2 Assumptions

(1) Unless specifically stated, EN 1990, EN 1991 (all parts) and the other relevant parts of EN 1993-1 (all parts) apply.

(2) The design methods given in EN 1993-1-8 are applicable if:

— the execution quality is as specified in EN 1090-2,

and

— the construction materials and products used are as specified in the relevant parts of EN 1993 (all parts), or in the relevant material and product specifications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1090-2:2018, *Execution of steel structures and aluminium structures — Part 2: Technical requirements for steel structures*

EN 1990, *Eurocode — Basis of structural and geotechnical design*

EN 1991 (all parts), *Eurocode 1 — Actions on structures*

EN 1993 (all parts), *Eurocode 3 — Design of steel structures*

EN 1993-1-1:2022, *Eurocode 3 — Design of steel structures — Part 1-1: General rules and rules for buildings*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1993-1-1 and the following apply.

¹ Under preparation. Stage at the time of publication: prCEN/TS 1993-1-801.

3.1.1

joint

zone where two members are interconnected

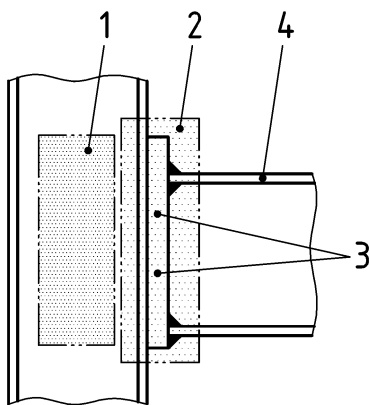
3.1.2

joint configuration

type or layout of the joint or joints in a zone within which the axes of two or more inter-connected members intersect

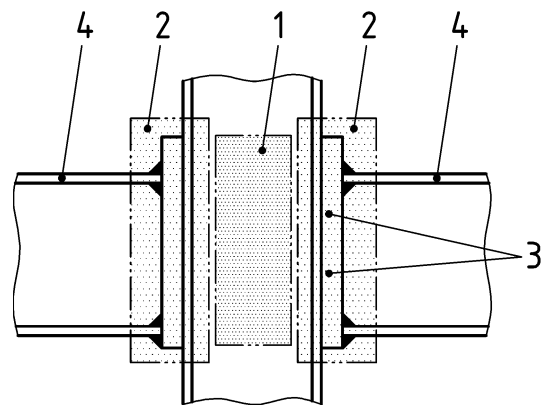
Note 1 to entry: See Figure 3.1 and Figure 8.1.

Note 2 to entry: An in-plane major-axis beam-to-column joint consists of a web panel and either one connection (single-sided joint configuration) or two connections (double-sided joint configuration).



Joint = web panel in shear + connection

a) Single-sided joint configuration



Left Joint = web panel in shear + left connection
Right joint = web panel in shear + right connection

b) Double-sided joint configuration

Key

- 1 web panel in shear
- 2 connection
- 3 components (e.g. bolts, end plate)
- 4 supported member

Figure 3.1 — Parts of a major-axis beam-to-column joint configuration

3.1.3

connection

set of components used to transfer forces and/or moments at the interface of the two connected members in a joint

3.1.4

connected member

any member that is joined to another member

3.1.5

basic component

basic component of a joint

part of a joint that makes a contribution to one or more of its structural properties

3.1.6**structural properties**

structural properties of a joint

resistance to internal forces and moments in the connected members, rotational stiffness and rotation capacity

3.1.7**rotational stiffness**

moment required to produce a unit rotation in a joint

3.1.8**rotation capacity**

angle through which the joint can rotate for a given plastic resistance

3.1.9**injection bolt**

special bolt that allows filling of the clearance between the bolt and the inside surface of the hole by injecting resin through a small hole in the head of the bolt

3.1.10**uniplanar joint**

joint that connects members in a lattice structure that are situated in a single plane

3.1.11**multiplanar joint**

joint that connects members in a lattice structure that are situated in more than one plane

3.1.12**column base**

zone where a column is connected to a concrete foundation by means of anchor bolts or fasteners between steel and concrete

Note 1 to entry: The determination of the structural properties does not include the own global response of the concrete block, e.g. creep, and the block to soil interaction.

3.2 Symbols and abbreviations

For the purposes of this document, the following symbols apply.

Clause 4

γ_C	partial factor for resistance of concrete;
γ_M	partial factor (general);
γ_{M0}	partial factor for resistance of cross-sections;
γ_{M1}	partial factor for resistance of members to instability assessed by member checks;
γ_{M2}	partial factor for resistance of cross-sections in tension to fracture, and partial factor for resistance of bolts, rivets, pins, welds and plates in bearing;
γ_{M3}	partial factor for slip resistance at ultimate limit state (Category C);
$\gamma_{M3,ser}$	partial factor for slip resistance at serviceability limit state (Category B);
γ_{M4}	partial factor for bearing resistance of injection bolts;

γ_{M5}	partial factor for resistance of hollow section joints;
$\gamma_{M6,ser}$	partial factor for resistance of pins at serviceability limit state;
γ_{Mu}	partial factor for resistance of components when verifying structural integrity (tying resistance);

Clause 5

A	gross cross-sectional area of fastener (bolt or pin);
A_0	area of rivet hole;
A_f	area of one flange of channel or similar connected member;
A_{gv}	gross area subject to shear;
A_{leg1}	area of angle leg (connected member), which is connected to lug angle;
A_{leg2}	area of angle leg (connected member), which is connected to supporting part;
A_m	cross-sectional area of connected member;
A_{net}	net area of angle section;
A_{nt}	net area subject to tension;
A_{nv}	net area subject to shear;
A_s	tensile stress area of bolt;
A_w	area of web of channel or similar connected member;
$B_{p,Rd}$	design value of punching shear resistance;
$F_{b,Ed}$	design value of bearing force of bolt or pin;
$F_{b,Ed,ser}$	design value of bearing force at serviceability limit state;
$F_{b,Rd}$	design value of bearing resistance of bolt or pin;
$F_{b,Rd,ser}$	design value of bearing resistance at serviceability limit state;
$F_{b,Rd,resin}$	design value of bearing resistance of resin;
$F_{b,x,Ed}$ and $F_{b,y,Ed}$	orthogonal components of $F_{b,Ed}$;
$F_{b,x,Rd}$ and $F_{b,y,Rd}$	orthogonal components of $F_{b,Rd}$;
F_{Ed}	design value of axial force;
$F_{p,C}$	bolt preloading force;
$F_{s,Rd}$	design value of slip resistance of bolt at ultimate limit state;
$F_{s,Rd,ser}$	design value of slip resistance of bolt at serviceability limit state;
$F_{t,Ed}$	design value of tension force of bolt or rivet at ultimate limit state;

$F_{t,Ed,ser}$	design value of tension force of bolt at serviceability limit state;
$F_{t,Rd}$	design value of tension resistance of bolt or rivet;
$F_{v,Ed}$	design value of shear force of fastener at ultimate limit state;
$F_{v,Ed,ser}$	design value of shear force of bolt at serviceability limit state;
$F_{v,Rd}$	design value of shear resistance of fastener;
L	minimum distance between adjacent fasteners in staggered rows (see Figure 5.3);
L_j	distance between centres of end fasteners of a joint measured parallel to the direction of force transfer;
L_t	thread engagement length;
M_{Ed}	design value of bending moment;
M_{Rd}	design value of bending moment resistance;
$M_{Ed,ser}$	design value of bending moment of pin at serviceability limit state;
$M_{Rd,ser}$	design value of bending moment resistance of pin at serviceability limit state;
$N_{u,Rd}$	design value of ultimate resistance to axial force of net cross-section of angle at holes for fasteners;
$V_{eff,1,Ed}$	design value of shear force, see Fig. 5.13;
$V_{eff,1,Rd}$ or $V_{eff,2,Rd}$	design value of block tearing resistance;
W_{el}	elastic section modulus;
a	shortest distance from edge of pin hole to edge of member measured parallel to the direction of force, see Table 5.3;
c	shortest distance from edge of pin hole to edge of member measured perpendicular to the direction of force, see Table 5.3;
d	diameter of fastener (bolt, pin or rivet);
d_0	hole diameter of bolt or pin;
d_m	mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller;
e_1	end distance from centre of fastener hole to nearest end, measured parallel to the direction of load transfer, see Figure 5.3;
e_2	edge distance from centre of fastener hole to nearest edge, measured perpendicular to the direction of load transfer, see Figure 5.3;
e_3	distance from the axis of slotted hole to nearest end or edge, see Figure 5.3;
e_4	distance from the centre of end radius of slotted hole to nearest end or edge, see Figure 5.3;
$f_{b,resin}$	bearing strength of resin;
$f_{H,Rd}$	design value of Hertz pressure;
f_u	ultimate tensile strength;

f_{ub}	ultimate tensile strength of bolt;
f_{up}	ultimate tensile strength of pin;
f_{ur}	specified ultimate tensile strength of rivet;
f_y	yield strength;
f_{yb}	yield strength of bolt;
f_{yp}	yield strength of pin;
g	gap;
k_b	bearing resistance reduction factor for bolts in slotted holes;
k_m	material reduction factor for bearing resistance;
k_s	bearing resistance reduction factor depending on hole clearance;
k_t	bearing resistance adjustment factor;
m	difference between normal round hole and oversize or slotted hole dimensions (in mm);
n	number of the friction planes or number of fastener holes on the shear face;
p_1	spacing between centres of fasteners measured parallel to the direction of force transfer, see Figure 5.3;
$p_{1,0}$	spacing between centres of edge fasteners measured parallel to the direction of force transfer, see Figure 5.3;
$p_{1,i}$	spacing between centres of inner fasteners measured parallel to the direction of force transfer, see Figure 5.3;
p_2	spacing between centres of inner fasteners measured perpendicular to the direction of force transfer, see Figure 5.3;
t	thickness;
$t_{b,resin}$	effective bearing thickness of resin;
t_p	thickness of plate;
t_{pp}	thickness of packing plates;
x	distance of shear plane to the beginning of transition region between bolt shank and threads;
α	geometrical factor for pins;
α_b or $\alpha_{b,red}$	adjustment factor for bearing resistance;
α_v	shear resistance reduction factor;
β	coefficient to account for thickness ratio of connected plates;
β_{LF}	reduction factor for long joints;
β_p	reduction factor for joints with fasteners with packings;
γ_{M0}	partial factor for resistance of cross-sections;
γ_{M2}	partial factor for resistance of cross-sections in tension to fracture, AND partial factor for resistance of bolts, rivets, pins, and plates in bearing;

γ_{M3}	partial factor for slip resistance at ultimate limit state (Category C);
$\gamma_{M3,ser}$	partial factor for slip resistance at serviceability limit state (Category B);
γ_{M4}	partial factor for bearing resistance of injection bolts;
$\gamma_{M6,ser}$	partial factor for resistance of pins at serviceability limit state;
ε	material parameter depending on f_y ;
μ	slip factor;
ΣF_{Rd}	design value of resistance of a group of fasteners;
$\sigma_{H,Ed,ser}$	contact stress for a pin bearing against a plate at serviceability limit state;

Clause 6

A_w	design throat area;
$F_{w,Ed}$	design value of weld force per unit length;
$F_{w,Rd}$	design value of weld resistance per unit length;
L_1 or L_2	distance between weld elements in intermittent fillet welds;
L_j	overall length of the welded lap joint parallel to the direction of force transfer;
L_w	length of weld element in intermittent welds;
L_{we}	length of intermittent weld at end of connected parts;
$L_{w,f}$	length of fillet weld;
L_{tot}	total length of intermittent weld;
a	design throat thickness;
$a_{nom,1}$ and $a_{nom,2}$	total nominal throat thickness in full penetration T-butt joints;
b or b_1	width;
b_{eff}	effective width of unstiffened T-joints;
b_p	width of plate welded to I or H section;
c_{nom}	unwelded gap in full penetration T-butt joints;
e	load eccentricity;
f_u	ultimate tensile strength of the lower steel grade of the connected elements;
$f_{u,FM}$	ultimate tensile strength of filler material;
$f_{u,p}$	ultimate tensile strength of plate welded to I or H section;
$f_{vw,d}$	design shear strength of weld;
f_y	yield strength;

$f_{y,f}$	yield strength of flange of I or H section;
$f_{y,p}$	yield strength of plate welded to I or H section;
k	parameter for determining the effective width;
r	radius of root fillet;
s	geometrical parameter;
t or t_1	thickness;
t_f	thickness of flange;
t_p	thickness of plate;
t_{pp}	thickness of packing plates;
t_w	thickness of web;
z	leg length;
z_{req}	required leg length;
$\beta_{Lw,i}$	reduction factor for long welds;
β_w	correlation factor for fillet welds;
$\beta_{w,mod}$	modified correlation factor for fillet welds;
ε	material parameter depending on f_y ;
γ_{M0}	partial factor for resistance of cross-sections;
γ_{M2}	partial factor for resistance of welds;
$\sigma_{v,Rd}$	resistance of butt welded connections;
$\sigma_{\parallel}$	normal stress parallel to the axis of weld;
$\sigma_{\perp}$	normal stress perpendicular to throat section;
$\tau_{\parallel}$	shear stress acting in the throat section parallel to the axis of weld;
$\tau_{\perp}$	shear stress perpendicular to the axis of weld;

Clause 7

E	modulus of elasticity of steel;
K_b	mean value of I_b/L_b for all the beams at the top of that storey;
K_c	mean value of I_c/L_c for all the columns in that storey;
I	moment of inertia (second moment of area);
I_b and I_c	moment of inertia (second moment of area) (subscripts “b” and “c” for beam and column, respectively);
L	system length of member;
L_b	span of beam (centre-to-centre columns);

L_c	storey height;
$M_{b,Ed}$ and $M_{c,Ed}$	design value of bending moment at the periphery of the web panel (subscripts “b” and “c” for beam and column, respectively);
$M_{b,pl,Rd}$ and $M_{c,pl,Rd}$	design value of plastic bending moment resistance (subscripts “b” and “c” for beam and column, respectively);
M_j	bending moment applied to a joint;
$M_{j,b,Ed}$ and $M_{j,c,Ed}$	design value of bending moment at intersection of member centrelines (subscripts “b” and “c” for beam and column, respectively);
$M_{j,Ed}$	design value of bending moment of a joint;
$M_{j,Rd}$	design value of bending moment resistance of a joint;
$N_{b,Ed}$ and $N_{c,Ed}$	design value of axial force at the periphery of the web panel (subscripts “b” and “c” for beam and column, respectively);
$N_{j,b,Ed}$ and $N_{j,c,Ed}$	design value of axial force at intersection of member centrelines (subscripts “b” and “c” for beam and column, respectively);
$N_{j,Ed}$	design value of axial force of a joint;
Q_f	chord stress function;
S_j	secant rotational stiffness of joint;
$S_{j,ini}$	initial rotational stiffness of joint;
$S_{j,\eta}$	design rotational stiffness of joint;
$V_{b,Ed}$ and $V_{c,Ed}$	design value of shear force at the periphery of the web panel (subscripts “b” and “c” for beam and column, respectively);
$V_{j,b,Ed}$ and $V_{j,c,Ed}$	design value of shear force at intersection of member centrelines (subscripts “b” and “c” for beam and column, respectively);
$V_{j,Ed}$	design value of shear force of a joint;
$V_{wp,Ed}$	design value of shear force of column web panel;
d_0	diameter of chord;
e	eccentricity in a joint in hollow section lattice girders, positive away from the braces;
h_0	depth of chord in the plane of the lattice girder;
k_{br}	factor to account for efficiency of the bracing;
y_s	distance from neutral axis to the outside web face of a channel section;
z	lever arm;
β	transformation parameter;
η	stiffness modification coefficient;

$\bar{\lambda}_0$	slenderness of a pin-ended column;
μ	stiffness ratio;
ψ	shape factor for the nonlinear part of the moment-rotation curve;
ϕ	joint rotation;
ϕ_{Cd}	design value of rotation capacity of a joint;
ϕ_{Ed}	design value of rotation of a joint;
ϕ_{Xd}	joint rotation at which $M_{j,Ed}$ first reaches $M_{j,Rd}$;

Clause 8

A_s	tensile stress area of bolt;
$F_{b,Ed}$	design value of bearing force of bolt;
$F_{c,Ed}$	design value of compression force;
$F_{C,Rd}$	design value of compression resistance of an equivalent T-stub;
$F_{c,Rd}$	design value of compression resistance;
F_{Rdu}	design value of concentrated resistance force as given in EN 1992-1-1;
$F_{t,Ed}$	design value of tension force;
$F_{T,Rd}$	design value of tension resistance of equivalent T-stub in tension;
$F_{T,i,Rd}$	design value of tension resistance of equivalent T-stub in tension for mode i ($i = 1, 2, 3$, or 1-2);
$F_{t,Rd}$	effective design tension resistance of bolt row r ;
$F_{t,r,Rd}$	design value of tension resistance of equivalent T-stub in tension for mode i ($i = 1, 2, 3$, or 1-2);
$F_{v,Ed}$	design value of shear force of bolt;
L_b	bolt elongation length;
M	bending moment;
$M_{b,Ed}$	design value of bending moment of beam at the periphery of the web panel;
$M_{bp,Rd}$	design value of bending moment resistance of backing plates;
$M_{pl,i,Rd}$	design value of plastic bending moment resistance of equivalent T-stub in tension for mode i ($i = 1$, or 2);
Q	prying force;
S_j	secant rotational stiffness of joint;
V	shear force;
$V_{wp,Ed}$	design value of shear force of column web panel;

a	design throat thickness;
b_{eff}	effective width of equivalent T-stub;
c	additional bearing width;
d_w	diameter of washer, or width across points of bolt head or nut;
e	edge distance;
f_{jd}	design bearing strength of joint for partially loaded areas;
f_y	yield strength;
$f_{y, \text{bp}}$	yield strength of backing plates;
l_{eff}	effective length of equivalent T-stub in tension;
m	distance from bolt centre to 20 % distance into profile root or weld;
n	effective edge distance;
n_b	number of bolt rows in tension (with 2 bolts per row);
t_{bp}	thickness of backing plates;
t_f	thickness of the flange of equivalent T-stub;
z	lever arm;
β_j	concrete joint material coefficient;
γ_{M0}	partial factor for resistance of cross-sections;

Clause 9

A_0	cross-sectional area of chord;
A_i	cross-sectional area of brace member i ($i = 1, 2$ or 3);
$A_{v,0,\text{gap}}$	effective shear area of chord in gap region;
C_1	exponent for a chord stress function, defined in the relevant table;
C_{ui}	ratio of ultimate tensile strength to yield strength of overlapping member;
C_{uj}	ratio of ultimate tensile strength to yield strength of overlapped member;
C_f	material factor;
E	modulus of elasticity of steel;
$M_{ip,0,\text{Ed}}$	design value of in-plane bending moment in chord;
$M_{ip,i,\text{Ed}}$	design value of in-plane bending moment in brace member i ($i = 1, 2$ or 3);
$M_{ip,0,\text{Rd}}$	design value of in-plane bending moment resistance of chord;
$M_{ip,i,\text{Rd}}$	design value of in-plane bending moment resistance of brace member i ($i = 1, 2$ or 3);
$M_{op,i,\text{Ed}}$	design value of out-of-plane bending moment in brace member i ($i = 1, 2$ or 3);
$M_{op,i,\text{Rd}}$	design value of out-of-plane bending moment resistance of brace member i ($i = 1, 2$ or 3);

$N_{0,Ed}$	design value of axial force applied to chord which gives the lowest value of Q_f ;
$N_{0,gap,Ed}$	design value of axial force applied to the chord at the gap of a K-joint;
$N_{0,Rd}$	design value of axial resistance of chord;
$N_{i,Ed}$	design value of axial force applied to brace member i ($i = 1, 2$ or 3);
$N_{i,Rd}$	design value of axial resistance of brace member i ($i = 1, 2$ or 3);
$N_{s,Rd}$	design value of shear resistance of brace(s) at connection with chord;
$N_{0,V,Rd}$	design value of axial resistance of chord reduced to account for shear force $V_{0,gap,Ed}$;
Q_f	chord stress function;
$V_{0,Ed}$	design value of shear force applied to chord;
$V_{0,gap,Ed}$	design value of shear force in the chord at the gap of a K-joint configuration;
$V_{0,gap,Rd}$	design value of shear resistance of chord at the gap of a K-joint configuration;
$V_{0,Rd}$	design value of shear resistance of chord;
$W_{ip,el,0}$	elastic section modulus of chord in the plane of the joint;
$W_{ip,pl,0}$	plastic section modulus of chord in the plane of the joint;
$W_{op,el,0}$	elastic section modulus of chord out of the plane of the joint;
$W_{op,pl,0}$	plastic section modulus of chord out of the plane of the joint;
$W_{ip,el,i}$	elastic section modulus of brace member i ($i = 1, 2$ or 3) in the plane of the joint;
$W_{op,el,i}$	elastic section modulus of brace member i ($i = 1, 2$ or 3) out of the plane of the joint;
a	throat thickness;
b_0	width of RHS chord;
$b_{e,ov}$	effective width of overlapping brace to overlapped brace connection;
$b_{e,p}$	effective width of RHS brace member for punching shear;
b_{eff}	effective width of RHS brace member to chord connection;
b_i	out-of-plane width of RHS brace member i ($i = 1, 2$ or 3);
b_p	width of reinforced flange plate;
b_w	effective width of web of I- or H-section chord;
c_s	factor;
$d_{e,ov}$	effective width of overlapping CHS brace member at connection to overlapped brace;
d_{eff}	effective width of CHS brace member to chord connection;
$d_{e,p}$	effective width of CHS brace member for punching shear;
d_0	chord diameter;
d_i	brace member i ($i = 1, 2$ or 3) diameter;
e	eccentricity in a joint in hollow section lattice girders, positive away from the braces;
f_b	buckling strength of the chord side wall;

f_{u0}	ultimate tensile strength of chord member;
f_{ui}	ultimate tensile strength of brace member i ($i = 1, 2$ or 3) or overlapping brace;
f_{uj}	ultimate tensile strength of overlapped brace;
f_{bp}	buckling strength of reinforcing flange plate;
f_y	yield strength;
f_{y0}	yield strength of chord member;
f_{yi}	yield strength of brace member i ($i = 1, 2$ or 3);
f_{yp}	yield strength of plate;
g or g_t	gap between brace members;
h_0	depth of RHS chord;
h_i	in-plane depth of RHS brace member i ($i = 1, 2$ or 3);
h_w	depth of the web of an I or H section chord member;
h_z	distance between centroids of the effective width parts of RHS connected to I or H section column section;
$l_{b,eff}$	effective perimeter for brace failure in overlapping brace;
l_p	depth of reinforced flange plate;
n_0	chord stress ratio;
p	distance, see Figure 9.2;
q	overlap between the brace members in a K- or N-joint configuration, see Figure 9.2;
r	radius of root fillet of I- or H-section chord;
t_0	wall thickness of chord;
t_f	thickness of flange;
t_i	wall thickness of brace member i ($i = 1, 2$ or 3);
t_p	thickness of plate;
t_w	thickness of web of I, H or channel section chord;
y_s	distance from the neutral axis to the outside web face of channel section;
α	factor for determining the effective shear area of a chord member in the gap area;
β	ratio of diameter or width of brace members to chord (subscript “p” for flange reinforcing plates);
γ	ratio of chord width or diameter to twice its wall thickness;
γ_{M5}	partial factor for resistance of hollow section joints;
ε	material parameter depending on f_y ;
η	ratio of the brace member depth to chord diameter or width (subscript “p” for flange reinforcing plates);
κ	maximum M - N interaction utilisation factor;
$\bar{\lambda}$	slenderness;

λ_{ov}	overlap ratio;
θ_i	acute angle between the chord and brace member i ($i = 1, 2$ or 3);
μ	multiplanar factor defined in the relevant table;
χ	reduction factor for flexural buckling;
φ	angle between planes in multiplanar joint configurations;

Annex A

A_s	tensile stress area of bolt;
A_{wp}	area of column web panel;
E	modulus of elasticity of steel;
E_{cm}	secant modulus of elasticity of concrete;
$F_{b,Rd}$	design value of bearing resistance of bolt;
$F_{c,bp,Rd}$	design value of resistance of concrete and base plate in compression;
$F_{c,fb,Rd}$	design value of resistance of beam (or column) flange and web in compression;
$F_{c,wc,Rd}$	design value of resistance of column web in transverse compression;
$F_{T,Rd}$	design value of resistance of equivalent T-stub in tension;
$F_{t,bp,Rd}$	design value of resistance of base plate in bending under tension;
$F_{t,cl,Rd}$	design value of resistance of angle flange cleat in bending;
$F_{t,ep,Rd}$	design value of resistance of end plate in bending;
$F_{t,fc,Rd}$	design value of resistance of column flange in bending;
$F_{t,wb,Rd}$	design value of resistance of beam web in tension;
$F_{t,wc,Rd}$	design value of resistance of column web in transverse tension;
$F_{v,Ed}$	design value of shear force of bolt;
$F_{vb,Rd}$	design value of shear resistance of anchor bolt;
L_b	bolt elongation length;
$M_{c,Rd}$	design value of bending moment resistance of beam section;
$\bar{S}_b$	relative bearing stiffness;
$V_{wp,add,Rd}$	design value of additional shear resistance of stiffened column web panel;
$V_{wp,Ed}$	design value of shear force in column web panel;
$V_{wp,Rd}$	design value of shear resistance of unstiffened column web panel;
a	throat thickness of fillet weld (subscripts “b”, “c” and “p” for beam, column, and plate respectively);
b_{cl}	width of angle cleat;

$b_{\text{eff,b,fc}}$	effective width of unstiffened column flange in bending, in welded connections;
$b_{\text{eff,c,wc}}$	effective width of column web in transverse compression;
$b_{\text{eff,t,wb}}$	effective width of beam web in tension;
$b_{\text{eff,t,wc}}$	effective width of column web in transverse tension;
b_{fb}	width of beam flange;
b_{fc}	width of column flange;
b_{p}	width of end plate;
b_{s}	width of supplementary web plate;
d	diameter of bolt;
d_0	hole diameter of bolt;
d_{M16}	nominal diameter of an M16 bolt;
d_{s}	distance between centrelines of stiffeners;
d_{wc}	depth of straight portion of column web (clear depth);
e	edge distance (subscript "X" for extension of end plate);
e_1	distance from the bolt row to the free edge of the plate in the direction of load transfer;
e_{c}	distance from the centre of the holes in the end row to the adjacent free end of the column flange measured in the direction of the axis of the column profile;
e_{bp}	end distance from the centre of bolt hole to the adjacent edge of the column flange backing plate;
h_{bp}	depth of column flange backing plate;
f_{u}	ultimate tensile strength;
f_{y}	yield strength;
f_{yb}	yield strength of anchor bolt;
$f_{\text{y,fc}}$	yield strength of column flange;
$f_{\text{y,st}}$	yield strength of stiffener;
$f_{\text{y,wb}}$	yield strength of beam web;
$f_{\text{y,wc}}$	yield strength of column web;
h	depth of beam;
h_{st}	depth of end-plate stiffener, see Figure A.9;
h_{wc}	inner depth of column web between flanges;
k_{b}	stiffness coefficient of bolts in bearing;
$k_{\text{c,bp}}$	stiffness coefficient of concrete and base plate in compression;
$k_{\text{c,fb}}$	stiffness coefficient of beam flange and web in compression;

$k_{c,p}$	stiffness coefficient of plate in compression;
$k_{c,wc}$	stiffness coefficient of column web in transverse compression;
k_{hb}	stiffness coefficient of beam haunch;
k_t	stiffness coefficient of bolts in tension, for a single bolt row;
k_{tb}	stiffness coefficient of anchor bolts in tension;
$k_{t,bp}$	stiffness coefficient of base plate in bending under tension;
$k_{t,cl}$	stiffness coefficient of angle flange cleat in bending;
$k_{t,ep}$	stiffness coefficient of end plate in bending;
$k_{t,fc}$	stiffness coefficient of column flange in bending;
$k_{t,p}$	stiffness coefficient of plate in tension;
$k_{t,wb}$	stiffness coefficient of beam web in tension;
$k_{t,wc}$	stiffness coefficient of column web in transverse tension;
k_v	stiffness coefficient of bolts in shear, for a single bolt row;
k_w	stiffness coefficient of welds;
k_{wp}	stiffness coefficient of column web panel in shear;
k_{wc}	reduction factor for interaction with normal stresses in the column web panel;
l_{eff}	effective length of equivalent T-stub in tension (subscripts “cp” and “nc” for circular and non-circular yield line patterns, respectively);
l_s	length of supplementary web plate;
l_{st}	length of end-plate stiffener, see Figure A.9;
m	distance from bolt centre to 20 % distance into profile root or weld (subscript “X” for the extension of the end plate);
n	number of bolts;
n_b	number of bolt rows (with two bolts per row);
p	spacing between centres of bolts (“pitch”);
p_1	spacing of the bolt-rows in the direction of load transfer
r	radius of root fillet (subscripts “b”, “c” and “cl” for beam, column, and angle cleat respectively);
s_p	length obtained by dispersion at 45° through the end plate;
s_s	length of stiff bearing;
t_{cl}	thickness of angle cleat;
t_{fb}	thickness of beam flange;
t_{fc}	thickness of column flange;

t_j	thickness of component j ;
t_p	thickness of plate;
t_s	thickness of supplementary web plate;
$t_{w,eff}$	effective thickness of stiffened column web;
t_{wb}	thickness of beam web;
t_{wc}	thickness of column web;
u	bolt hole elongation;
w	horizontal spacing between lines of bolts in an end plate connection ("gauge");
z	lever arm;
α	modification coefficient for yield line patterns adjacent to stiffener or flange;
α_{bc}	coefficient;
β	transformation parameter;
γ_{M0}	partial factor for resistance of cross-sections;
γ_{M1}	partial factor for resistance of members to instability assessed by member checks;
γ_{M2}	partial factor for resistance of bolts;
ε	material parameter depending on f_y ;
η	factor for shear area;
$\bar{\lambda}_p$	plate slenderness;
ρ	reduction factor for plate buckling;
$\bar{\sigma}_b$	non-dimensional average bearing stress;
$\bar{\sigma}_{b,Ed}$	non-dimensional design bearing stress;
$\sigma_{com,Ed}$	maximum longitudinal compressive stress due to axial force and bending moment in a column;
ω	reduction factor for interaction with shear in the column web panel;

Annex B

E	modulus of elasticity of steel;
$F_{c,fb,Rd}$	design value of resistance of beam flange and web in compression;
$F_{c,wc,Rd}$	design value of resistance of column web in transverse compression;
$F_{r,Rd}$	bolt row r force ($r = 1$, or 2);
F_{Rd}	total design resistance;
$F_{t,Rd}$	design value of tension resistance of a bolt;
$F_{t,ep,Rd}$	design value of resistance of end plate in bending;

$F_{t,fc,Rd}$	design value of resistance of column flange in bending;
$F_{t,r,Rd}$	effective design tension resistance of bolt row r ;
$F_{t,wb,Rd}$	design value of resistance of beam web in tension;
$F_{t,wc,Rd}$	design value of resistance of column web in transverse tension;
$F_{t,x,Rd}$	effective design tension resistance of bolt row x ;
$M_{j,Ed}$	design value of bending moment applied to a joint;
$M_{j,Rd}$	design value of bending moment resistance of a joint;
$M_{pl,Rd}$	design value of plastic resistance to bending moment of the connected member;
N_{Ed}	design value of axial force of a connected member;
$N_{j,Ed}$	design value of axial force applied to a joint;
$N_{j,Rd}$	design value of axial resistance of a joint;
$S_{j,ini}$	initial rotational stiffness of joint;
$V_{j,Ed}$	design value of shear force of a joint;
$V_{j,Rd}$	design value of shear resistance of a joint;
$V_{wp,Rd}$	design value of shear resistance of unstiffened column web panel;
d	diameter of bolt;
f_{ub}	ultimate tensile strength of bolt;
f_y	yield strength;
h_b	depth of beam;
h_c	depth of column;
h_r	distance from bolt row r to centre of compression;
h_x	distance from bolt row x to centre of compression;
k_b	stiffness coefficient of bolts in bearing;
$k_{c,wc}$	stiffness coefficient of column web in transverse compression;
$k_{eff,r}$	effective stiffness coefficient of bolt row r ;
k_{eq}	equivalent stiffness coefficient;
k_i	stiffness coefficient of basic component i ;
$k_{i,r}$	stiffness coefficient of component i relative to bolt row r ;
k_t	stiffness coefficient of bolts in tension, for a single bolt row;
$k_{t,cl}$	stiffness coefficient of angle flange cleat in bending;
$k_{t,ep}$	stiffness coefficient of end plate in bending;
$k_{t,fc}$	stiffness coefficient of column flange in bending;

$k_{t,wc}$	stiffness coefficient of column web in transverse tension;
k_v	stiffness coefficient of bolts in shear, for a single bolt row;
k_{wp}	stiffness coefficient of column web panel in shear;
t	thickness;
t_{cl}	thickness of angle cleat;
t_{fb}	thickness of beam flange;
z	lever arm;
z_{eq}	equivalent lever arm;
β	transformation parameter;
γ_{rm}	overstrength factor;
ϕ_{Cd}	design value of rotation capacity of a joint;

Annex C

A_v	shear area of supported beam or supporting member;
$A_{v,cl}$	shear area of cleat;
$A_{v,ep}$	shear area of end plate;
$A_{v,net}$	net shear area of supported beam or supporting member;
$A_{v,net,cl}$	net shear area of cleat;
$A_{v,fp}$	shear area of fin plate;
$A_{v,net,ep}$	net shear area of end plate;
$A_{v,net,fp}$	net shear area of fin plate;
E	modulus of elasticity of steel;
$F_{b,hor,Rd}$ and $F_{b,ver,Rd}$	vertical and horizontal components of $F_{b,Rd}$;
$F_{v,Rd}$	design value of shear resistance of bolt;
I	parameter;
T_{Ed}	design value of tying force;
$T_{u,w,Rd}$	design value of tying resistance of supporting web;
$T_{u,wb,Rd}$	design value of tying resistance of beam web;
$V_{b,fp,Rd}$	design value of shear resistance from buckling of fin plate;
$V_{c,ep,Rd}$	design value of shear resistance from bending of end plate;
$V_{c,fp,Rd}$	design value of shear resistance from bending of fin plate;

V_{Ed}	design value of shear force;
V_{Rd}	design value of shear resistance;
$V_{u,cl,Rd}$	design value of shear resistance of net section of leg of web cleat;
$V_{u,ep,Rd}$	design value of shear resistance of net section of end plate;
$V_{u,fp,Rd}$	design value of shear resistance of net section of fin plate;
$V_{u,Rd}$	design value of shear resistance of net section of supported beam or supporting member;
$V_{v,cl,Rd}$	design value of shear resistance of gross section of leg of web cleat;
$V_{v,ep,Rd}$	design value of shear resistance of gross section of end plate;
$V_{v,fp,Rd}$	design value of shear resistance of gross section of fin plate;
$V_{v,wb,Rd}$	design value of shear resistance of beam web;
a	throat thickness;
d_0	hole diameter of bolt;
d_{wb}	depth of straight portion of the supported beam web (clear depth);
d_2	depth of straight portion of web of supporting member (clear depth);
e_1	end distance;
e_2	edge distance;
h_{cl}	depth of cleat;
h_e	distance to beam bottom flange, see Table C.1;
h_{ep}	depth of end plate;
h_{fp}	depth of fin plate;
h_p	depth;
f_u	ultimate tensile strength OR ultimate tensile strength of the lower steel grade of the connected elements;
$f_{u,2}$	ultimate tensile strength of supporting member;
$f_{u,cl}$	ultimate tensile strength of cleat;
$f_{u,fp}$	ultimate tensile strength of fin plate;
f_y	yield strength;
$f_{y,cl}$	yield strength of cleat;
$f_{y,ep}$	yield strength of end plate;
$f_{y,fp}$	yield strength of fin plate;
$f_{y,wb}$	yield strength of beam web;
g_h	gap between connected members;

l_{eff}	effective length of equivalent T-stub in tension;
n	total number of bolts;
n_1	number of horizontal bolt rows;
n_2	number of vertical bolt rows;
p_1	vertical bolt spacing for end plate and fin plate connections ("pitch");
p_2	transverse distance between bolt centrelines in fin plate connections;
p_3	transverse distance between bolt centrelines ("gauge");
t	thickness;
t_{cl}	thickness of cleat;
t_{ep}	thickness of end plate;
t_{fp}	thickness of fin plate;
t_{wb}	thickness of beam web;
$t_{\text{w},2}$	thickness of web of supporting member;
z	eccentricity of shear force;
z_0	geometrical parameter;
z_p	distance from the face of the supporting member to the first vertical line of bolts;
α and α_1	parameter;
β and β_1	parameter;
β_w	correlation factor for fillet welds;
γ_1	parameter;
$\gamma_{\text{M}0}$	partial factor for resistance of cross-sections;
$\gamma_{\text{M}1}$	partial factor for resistance of members to instability assessed by member checks;
$\gamma_{\text{M}2}$	partial factor for resistance of cross-sections in tension to fracture, AND partial factor for resistance of bolts, welds and plates in bearing;
γ_{Mu}	partial factor for resistance of components when verifying structural integrity (tying resistance);
η_1	parameter;
λ_1	parameter;
$\bar{\lambda}_{\text{LT}}$	slenderness of fin plate;
χ_{LT}	reduction factor for lateral torsional buckling of fin plate;
ϕ_{Cd}	design value of rotation of capacity of a joint;
ϕ_{Ed}	design value of rotation of a joint;

Annex D

$C_{f,d}$	coefficient of friction between base plate and grout layer;
E	modulus of elasticity of steel;
$F_{C,Rd}$	design compressive resistance of one side of the joint;
$F_{c,bp,Rd}$	design value of resistance of concrete and base plate in compression;
$F_{c,fb,Rd}$	design value of resistance of beam (or column) flange and web in compression;
$F_{f,Rd}$	design value of friction resistance;
$F_{T,Rd}$	design value of tension resistance of one side of the joint;
$F_{t,bp,Rd}$	design value of resistance of base plate in bending under tension;
$F_{t,wc,Rd}$	design value of resistance of column web in transverse tension;
$F_{v,Rd}$	design value of shear resistance between column base plate and grout layer;
$F_{va,Rd}$	design value of shear resistance of a fastener between steel and concrete
$F_{vb,Rd}$	design value of shear resistance of anchor bolt;
M_{Ed}	design value of bending moment;
$M_{j,Rd}$	design value of moment resistance of a joint;
$N_{c,Ed}$	design value of normal compression force in column;
N_{Ed}	design value of axial force;
$N_{j,Rd}$	design value of axial resistance of a joint;
$S_{j,ini}$	initial rotational stiffness of joint;
e	eccentricity;
f_{jd}	design bearing strength of joint;
k_C	compression stiffness coefficient;
$k_{c,bp}$	stiffness coefficient of concrete and base plate in compression;
k_T	tension stiffness coefficient;
k_{tb}	stiffness coefficient of anchor bolts in tension;
$k_{t,bp}$	stiffness coefficient of base plate in bending under tension;
n	number of anchor bolts;
z	lever arm;
z_C and z_T	lever arms.

Other symbols are specified in appropriate clauses when they are used.

4 Basis of design

4.1 General rules

4.1.1 Basic requirements

(1) The design of steel structures shall be in accordance with the general rules given in EN 1990 and EN 1991 (all parts) and the specific design provisions for steel structures given in the other relevant parts of EN 1993-1 (all parts).

(2) Steel structures designed according to this document shall be executed according to EN 1090-2 with construction materials and products used as specified in the relevant parts of EN 1993, or in the relevant material and product specifications.

4.1.2 Additional requirements

(1) The provisions given in this document shall apply to steels complying with the requirements given in EN 1993-1-1, and to joints subject to predominantly static loading.

(2) The provisions given in this document should apply to material thickness greater than or equal to 3 mm, unless otherwise stated in individual clauses.

(3) Joints shall have a design resistance such that the structure complies with all the basic requirements given in this document and in EN 1993-1-1.

(4) The design of joints subject to loading other than static loading shall also comply with the principles given in the relevant parts of EN 1993, e.g. for joints subject to fatigue, see EN 1993-1-9.

4.2 Design assumptions

(1) The forces and moments applied to joints shall be determined according to the principles in EN 1993-1-1.

(2) Joints shall be designed on the basis of a realistic assumption of the distribution of internal forces through the basic components (see 3.1.5).

(3) The following assumptions should be used to determine the distribution of forces:

- a) the internal forces assumed in the joints are in equilibrium with the forces and moments applied to the joint,
- b) the forces implied by this distribution are not greater than the resistance of the basic components,
- c) the deformations implied by this distribution are not greater than the deformation capacity of the basic components,
- d) the assumed distribution of internal forces should be realistic with regard to relative stiffness within the joint.

NOTE The application rules given in this document comply with (3).

(4) Linear elastic, or elastic-plastic analysis may be used in the design of joints. A linear elastic distribution of internal forces within the joint may always be assumed. For steel grades higher than S460, an elastic distribution of forces within the joint should be assumed.

NOTE Rules for elastic-plastic analysis in the design of joints and plastic global structural analysis for steel grades higher than S460 can be set by the National Annex. In that case, relevant clauses such as 8.1(5) and B.5.1(2) can be changed accordingly.

4.3 Structural properties of joints

4.3.1 General

(1) The resistance of a joint should be based on the resistances of its components.

(2) The structural properties of joints may be determined analytically according to the rules given in this document. Alternatively, testing complying with EN 1990, numerical methods or other analytical methods may also be used.

NOTE 1 Relevant information on numerical methods can be found in EN 1993-1-14.

NOTE 2 Testing is in accordance with EN 1990:2023, Annex D: Design assisted by testing.

NOTE 3 Additional requirements and information on experimental testing can be set by the National Annex.

4.3.2 Partial factors

(1) The partial factors γ_M listed in Table 4.1 should be used for the calculation of the design resistance of different components in joints.

Table 4.1 — Partial factors

Structural component	Partial factor
Resistance of members and cross-sections	γ_{M0} , γ_{M1} and γ_{M2} , see EN 1993-1-1
Resistance of concrete	γ_c , see EN 1992-1-1
Resistance of bolts	γ_{M2}
Resistance of rivets	
Resistance of pins	
Resistance of welds	
Resistance of plates in bearing	
Slip resistance	γ_{M3}
— at ultimate limit state (Category C)	
— at serviceability limit state (Category B)	$\gamma_{M3,ser}$
Bearing resistance of injection bolts	γ_{M4}
Resistance of hollow section joints	γ_{M5}
Resistance of pins at serviceability limit state	$\gamma_{M6,ser}$
Tying resistance	γ_{Mu}

NOTE 1 The values for γ_M are as follows: $\gamma_{M2} = 1,25$; $\gamma_{M3} = 1,25$ and $\gamma_{M3,ser} = 1,1$; $\gamma_{M4} = 1,0$; $\gamma_{M5} = 1,0$; $\gamma_{M6,ser} = 1,0$; $\gamma_{Mu} = 1,1$, unless the National Annex gives different values.

NOTE 2 In the design formulae for hollow section joints in Clause 9, $\gamma_{M5} = 1,0$ is used because the partial factors are incorporated in the design rules.

4.4 Hybrid connections

(1) Where hybrid connections or connections with fasteners or welds with different stiffnesses are used, the distribution of forces through the connection should account for the different stiffness of the connections or fasteners or welds (see 4.2).

(2) Conservatively, the force may be assumed to be carried by the stiffer connection, or fasteners or welds.

4.5 Joints loaded in shear subject to impact, vibration and/or load reversal

(1) Where a joint loaded in shear is subject to impact or significant vibration one of the following connecting methods should be used:

- welding;
- bolts with locking devices;
- preloaded bolts;
- injection bolts;
- other types of bolts which effectively prevent movement of the connected parts;
- rivets.

(2) Where slip is not acceptable in a joint (e.g. because it is subject to reversal of shear load), preloaded bolts in a Category B or C connection (see 5.4.1), fit bolts (see 5.9.2), rivets or welding should be used.

(3) For wind and/or stability bracings, bolts in Category A connections (see 5.4.1) may be used.

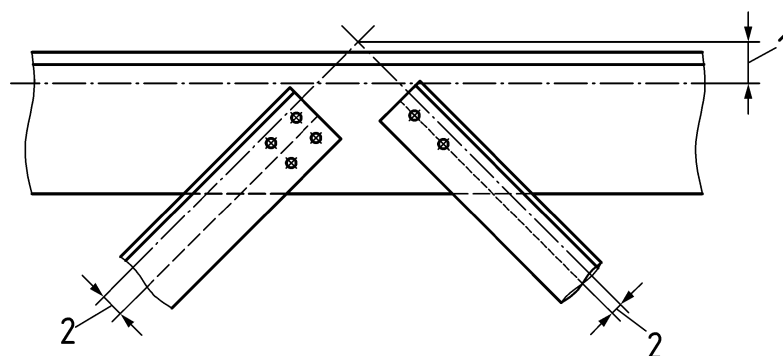
4.6 Eccentricity at intersections

(1) Where there is eccentricity at intersections, the joints and members should be designed for the resulting moments and forces, except in the case of particular types of structures where it has been demonstrated that this is not required, see 7.1.5.

(2) In the case of a joint where angles or tees are attached by either a single or double line of bolts, any eccentricity should be taken into account in accordance with (1). In-plane and out-of-plane eccentricities should be determined by considering the relative positions of the centroidal axis of the member and of the setting out line in the plane of the joint, see Figure 4.1. For a single angle in tension connected by bolts on one leg, the eccentricity between the setting out line and the centroid may be taken into account by using the simplified design method given in 5.15.

NOTE The effect of eccentricity on angles used as web members in compression is given in CEN/TR 1993-1-103².

² Under preparation.

**Key**

----	setting out line
.....	centroid
+	fastener
1	eccentricity of the centroids
2	eccentricity of the setting out line with respect to the centroid

Figure 4.1 — Setting out lines and intersection eccentricities**5 Connections using bolts, rivets or pins****5.1 Bolts, nuts and washers****5.1.1 Property classes**

(1) The properties of bolts, nuts and washers should be in accordance with EN 14399 (all parts), EN 15048 (all parts) and the standards given in EN 1090-2.

(2) The rules given in this document are valid for bolts of the property classes given in Table 5.1.

(3) The nominal values of yield strength f_{yb} and ultimate tensile strength f_{ub} of bolts given in Table 5.1 should be adopted as characteristic values in design calculations.

Table 5.1 — Nominal values of yield strength f_{yb} and ultimate tensile strength f_{ub} of bolts

Property class	4.6	4.8	5.6	5.8	6.8	8.8	10.9
f_{yb} (N/mm ²)	240	320	300	400	480	640	900
f_{ub} (N/mm ²)	400	400	500	500	600	800	1 000

NOTE The National Annex can exclude certain property classes of bolts.

5.1.2 Preloaded bolts

(1) Preloaded bolt assemblies should be property class 8.8 and 10.9 and should conform to the relevant Parts of EN 14399, with controlled tightening in accordance with 8.5 of EN 1090-2:2018.

5.2 Rivets

(1) The material properties, dimensions and tolerances of steel rivets should be specified.

NOTE The material properties, dimensions and tolerances of steel rivets can be given in the National Annex.

(2) For rivets of steel grade S235 in shear only, the specified ultimate tensile strength f_{ur} may be taken as 400 N/mm².

(3) Single rivets should not be used in single lap joints.

5.3 Anchor bolts and fasteners between steel and concrete

(1) The following materials should be used for anchor bolts:

- steel grades conforming to EN 10025 (all parts), as relevant;
- steel grades conforming to EN 14399 (all parts), EN 15048 (all parts) and the standards given in EN 1090-2;
- steel grades used for reinforcing bars conforming to EN 10080;

provided that the nominal yield strength is not greater than 900 N/mm², or 640 N/mm² in case the anchor bolts are subject to shear.

(2) Dimensions and materials of fasteners between steel and concrete should follow EN 1992-4.

5.4 Bolted connections

5.4.1 Categories of bolted connections

(1) Bolted connections loaded in shear (shear connections) should be designed as one of the following:

a) Category A: Bearing type

Bolts from property class 4.6 up to and including property class 10.9 should be used. Preloading or special provisions for contact surfaces are not required. Bolts in normal round holes or bolts in slotted holes where the longitudinal axis of the slotted hole is perpendicular to the direction of the force should be used. The hole dimensions should not be greater than those specified in 6.6 of EN 1090-2:2018.

b) Category B: Slip-resistant at serviceability limit state

Preloaded bolts with controlled tightening in accordance with 5.1.2(1) should be used. Bolts in normal round holes or bolts in slotted holes where the longitudinal axis of the slotted hole is perpendicular to the direction of the force should be used. The hole dimensions should not be greater than those specified in 6.6 of EN 1090-2:2018.

c) Category C: Slip-resistant at ultimate limit state

Preloaded bolts with controlled tightening in accordance with 5.1.2(1) should be used.

(2) Bolted connections loaded in tension (tension connections) should be designed as one of the following:

a) **Category D: Non-preloaded**

Bolts from property class 4.6 up to and including property class 10.9 should be used. Preloading is not required. This category should not be used where the connections are frequently subject to variations of tensile loading. However, they may be used in connections designed to resist wind loads.

b) **Category E: Preloaded**

Preloaded bolts with controlled tightening in accordance with 5.1.2(1) should be used.

5.4.2 Injection bolts

(1) Injection bolts may be used as an alternative to ordinary bolts and rivets for category A, B and C connections specified in 5.4.1.

NOTE Fabrication and erection details for injection bolts are given in Annex J of EN 1090-2:2018.

5.4.3 Hybrid connections

(1) As an exception to 4.4(1), preloaded bolts in category C connections may be assumed to share shear load with welds, provided that the final tightening of the bolts is carried out after the welding is complete.

5.4.4 Connections with lug angles

(1) The lug angle shown in Figure 5.1 connects angle members and their fasteners to a supporting part. The lug angles and the connections with lug angles should be designed to transmit the design value of forces obtained from Table 5.2.

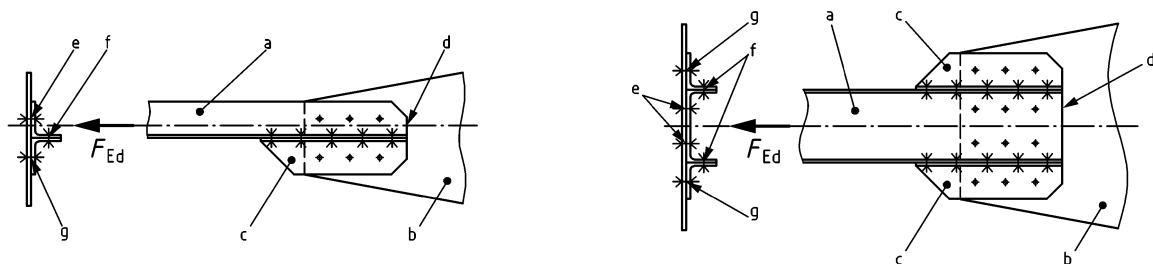
Table 5.2 — Actions used for the design of lug angles and connections with lug angles

	Lug angle under axial force ^a	Connections in shear		
		Lug angle-supporting part ^b	Lug angle-connected member ^c	Connected member – supporting part ^d
Angle members with lug angles, Figure 5.1a)	$1,2 \frac{A_{leg1}}{A_m} F_{Ed}$	$1,2 \frac{A_{leg1}}{A_m} F_{Ed}$	$1,4 \frac{A_{leg1}}{A_m} F_{Ed}$	$\frac{A_{leg2}}{A_m} F_{Ed}$
Channel or similar member with lug angles, Figure 5.1b)	$1,1 \frac{A_f}{A_m} F_{Ed}$	$1,1 \frac{A_f}{A_m} F_{Ed}$	$1,2 \frac{A_f}{A_m} F_{Ed}$	$\frac{A_w}{A_m} F_{Ed}$
A_{leg1} area of angle leg (connected member), which is connected to lug angle; A_{leg2} area of angle leg (connected member), which is connected to supporting part; A_f area of one flange of channel or similar connected member; A_w area of web of channel or similar connected member, which is connected to supporting part; A_m cross-sectional area of connected member; F_{Ed} design value of axial force acting in the connected member.				
NOTE Lug angles can be used to reduce the length of connection.				
^a See (c) in the key to Figure 5.1. ^b See (g) in the key to Figure 5.1. ^c See (f) in the key to Figure 5.1. ^d See (e) in the key to Figure 5.1.				

(2) There should be a minimum of two fasteners to connect a lug angle to a supporting part.

(3) The connection of a lug angle to a supporting part should terminate at the end of the member connected. The connection of the lug angle to the connected member should run from the end of the connected member to a point beyond the supporting part.

(4) The rules given in 5.4.4 are not applicable to steel grades higher than S460, in which case the force distribution should be determined in accordance with 4.2.



a) connection of angle member and lug angle to the supporting part

b) connection of channel and lug angles to the supporting part

Key

- a connected member (angle member or channel)
- b supporting part
- c lug angle
- d end of connected member
- e connection of the connected member to the supporting part
- f connection of the lug angle to the connected member
- g connection of the lug angle to the supporting part

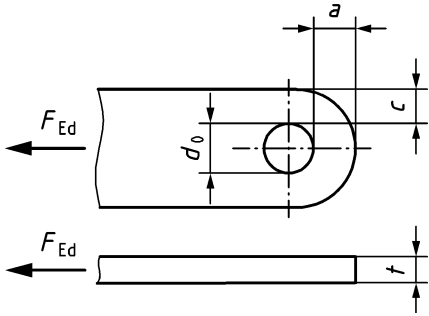
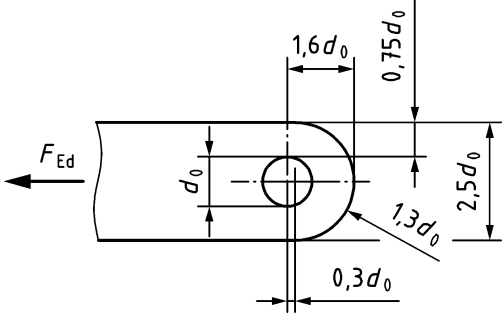
Figure 5.1 — Lug angles

5.5 Pin connections

(1) All pins should be secured.

(2) In members connected with pins, the geometry of the unstiffened element that contains a hole for the pin should comply with one of the two options for dimensional requirements given in Table 5.3. Members connected with pins should be arranged to avoid eccentricity.

Table 5.3 — Geometrical requirements for pin-ended members

<u>Option A:</u> Thickness t is known. 	$a \geq \frac{F_{Ed} \gamma_{M0}}{2 t f_y} + \frac{2 d_0}{3}$ $c \geq \frac{F_{Ed} \gamma_{M0}}{2 t f_y} + \frac{d_0}{3}$
<u>Option B:</u> Thickness t is unknown. 	$t \geq 0,7 \sqrt{\frac{F_{Ed} \gamma_{M0}}{f_y}}$ $d_0 \leq 2,5 t$

5.6 Riveted connections

(1) Riveted connections should be designed to transfer force through bearing in the plate and shear in the rivet.

NOTE Some tension forces can be present in a rivet and need to be accounted for, see 5.7.4(2).

(2) The grip length of rivets should not be greater than $4,5d$ for hammer riveting and $6,5d$ for press riveting, where d is the diameter of the rivets.

5.7 Design criteria

5.7.1 Design criteria for bolted connections

(1) The design criteria for shear and tension connections of categories A to E should follow Table 5.4.

(2) Bolts subject to a combination of shear force and tension force should also satisfy the criteria given in Table 5.9.

Table 5.4 — Design criteria for bolted connections

Category A — Bearing type shear connections
Design criteria at ultimate limit state: — The design value of bearing resistance $F_{b,Rd}$ should not be exceeded at any bolt hole. — The design value of shear resistance of a bolt $F_{v,Rd}$ should not be exceeded at any shear plane. Remarks: — Bolts of property class 4.6 to 10.9 should be used; — Preloading is not required; — $F_{v,Rd}$ and $F_{b,Rd}$ should be obtained from Table 5.9; — The design value of resistance of the connection should be obtained from 5.11.
Category B — Slip-resistant at serviceability limit state shear connections
Design criteria at ultimate limit state: — See Category A. Design criterion at serviceability limit state: — The design value of slip resistance $F_{s,Rd,ser}$ should not be exceeded. Remarks: — Preloaded bolting assemblies of property class 8.8 or 10.9 should be used; — $F_{s,Rd,ser}$ should be obtained from 5.10; — The design value of resistance of the connection should be obtained from 5.11 at ultimate limit state and from 5.12 at serviceability limit state.
Category C — Slip-resistant at ultimate limit state shear connections
Design criterion at ultimate limit state: — The design value of slip resistance $F_{s,Rd}$ should not be exceeded. Remarks: — Preloaded bolting assemblies of property class 8.8 or 10.9 should be used; — $F_{s,Rd}$ should be obtained from 5.10; — The design value of resistance of the connection should be obtained from 5.12.
Category D — Non-preloaded tension connections
Design criteria at ultimate limit state: — The design value of tension resistance of a bolt $F_{t,Rd}$ should not be exceeded. — The design value of punching shear resistance $B_{p,Rd}$ in any connected element should not be exceeded. Remarks: — Bolts of property class 4.6 to 10.9 should be used; — $F_{t,Rd}$ and $B_{p,Rd}$ should be obtained from Table 5.9; — The design tension force applied in the bolts in tension should include prying action, if any, see 5.9.5.
Category E — Preloaded tension connections
Design criteria at ultimate limit state — See Category D. Remark: — Preloaded bolting assemblies of property class 8.8 or 10.9 should be used. The design value of ultimate resistance of the net cross-section considering holes should be verified according to 8.2.3(5) of EN 1993-1-1:2022 for Categories A, B or C.

5.7.2 Design criteria for connections with injection bolts

(1) The design criteria for injection bolts in categories A, B and C connections should follow Table 5.5.

Table 5.5 — Design criteria for connections with injection bolts

Category A — Bearing type shear connections
Design criteria at ultimate limit state: — The design value of bearing resistance $F_{b,Rd}$ should not be exceeded at any bolt hole. — The design value of bearing resistance of the resin $F_{b,Rd,resin}$ should not be exceeded at any bolt hole. — The design value of shear resistance of a bolt $F_{v,Rd}$ should not be exceeded at any shear plane. Remarks: — Bolts of property class 8.8 or 10.9 should be used; — Preloading is not required; — $F_{v,Rd}$ and $F_{b,Rd}$ should be obtained from Table 5.9; — $F_{b,Rd,resin}$ should be obtained from 5.9.4(1); — The design value of resistance of the connection should be obtained from 5.11.
Category B — Slip-resistant at serviceability limit state shear connections
Design criteria at ultimate limit state: — See Category A. Design criterium at serviceability limit state: — The sum of the design value of slip resistance at serviceability limit state $F_{s,Rd,ser}$ and the design value of bearing resistance of the resin $F_{b,Rd,resin}$ should not be exceeded. Remarks: — Preloaded bolting assemblies of property class 8.8 or 10.9 should be used; — $F_{s,Rd,ser}$ should be obtained from 5.10; — $F_{b,Rd,resin}$ should be obtained from 5.9.4(1); — The design value of resistance of the connection should be obtained from 5.11 at ultimate limit state and from 5.12 at serviceability limit state.
Category C — Slip-resistant at ultimate limit state shear connections
Design criteria at ultimate limit state: — The design value of shear resistance of a bolt $F_{v,Rd}$ should not be exceeded at any shear plane. — The sum the design value of slip resistance $F_{s,Rd}$ and the design value of bearing resistance of the resin $F_{b,Rd,resin}$ should not be exceeded. Remarks: — Preloaded bolting assemblies of property class 8.8 or 10.9 should be used; — $F_{v,Rd}$ should be obtained from Table 5.9; — $F_{s,Rd}$ should be obtained from 5.10; — $F_{b,Rd,resin}$ should be obtained from 5.9.4(1); — The design value of resistance of the connection should be obtained from 5.12. The design value of ultimate resistance of the net cross-section considering holes should be verified according to 8.2.3(5) of EN 1993-1-1:2022 for Categories A, B or C.

5.7.3 Design criteria for pin connections

(1) The design criteria for solid circular pin connections should follow Table 5.6.

(2) The internal forces in a pin should be calculated on the basis that the connected parts form simple supports. It should be generally assumed that the reactions between the pin and the connected parts are uniformly distributed along the length in contact on each part. The following cases should be considered:

a) For a pin connection with three connecting parts, see Figure 5.2, the pin connection should be checked for the following combinations of bending moment M_{Ed} and shear force $F_{v,Ed}$:

— Symmetrical situation – maximum bending moment:

$$M_{Ed,1} = \frac{F_{Ed}}{8}(2t_1 + t_2 + 4g) \text{ and } F_{v,Ed,1} = 0 \quad (5.1)$$

— Symmetrical situation – maximum shear and corresponding bending moment:

$$M_{Ed,2} = \frac{F_{Ed}}{4}(t_1 + 2g) \text{ and } F_{v,Ed,2} = \frac{F_{Ed}}{2} \quad (5.2)$$

— Asymmetrical situation – maximum shear and corresponding bending moment:

$$M_{Ed,3} = \alpha \frac{F_{Ed}}{2} t_1 \text{ and } F_{v,Ed,3} = \alpha F_{Ed} \quad (5.3)$$

— Asymmetrical situation – high shear and high bending moment:

$$M_{Ed,4} = (1 - \alpha) \frac{F_{Ed}}{2} (t_1 + 4g) \text{ and } F_{v,Ed,4} = (1 - \alpha) F_{Ed} \quad (5.4)$$

where

$$\alpha = \frac{t_1 + t_2 + 4g}{2t_1 + 2t_2 + 4g} \quad (5.5)$$

The resistance of the external plate and the bearing resistance in the external plate and the pin, see Table 5.6, should be checked for αF_{Ed} .

NOTE 5.5(2) requires members to be connected with pins to be arranged to avoid eccentricities (symmetrical situation). However, unintended eccentricities can occur and are accounted for (asymmetrical situation) in Formulae (5.3) and (5.4).

b) For other pin connections, for example with more than three connected parts, the design internal forces should be derived accordingly.

Table 5.6 — Design criteria for pin connections

Failure mode	Design requirements
Design criteria for non-replaceable pins	
Design value of shear resistance of the pin	$F_{v,Rd} = \frac{0,6 A f_{up}}{\gamma_{M2}} \geq F_{v,Ed}$
Design value of bearing resistance of the plate and the pin	$F_{b,Rd} = \frac{1,5 d t f_y}{\gamma_{M0}} \geq F_{b,Ed}$
Design value of bending resistance of the pin	$M_{Rd} = \frac{1,5 W_{el} f_{yp}}{\gamma_{M0}} \geq M_{Ed}$
Combined shear and bending resistance in a cross-section of the pin	$\left(\frac{M_{Ed}}{M_{Rd}}\right)^2 + \left(\frac{F_{v,Ed}}{F_{v,Rd}}\right)^2 \leq 1$
Additional design criteria for replaceable pins	
Design value of bearing resistance of the plate and the pin	$F_{b,Rd,ser} = \frac{0,6 d t f_y}{\gamma_{M6,ser}} \geq F_{b,Ed,ser}$
Design value of bending resistance of the pin	$M_{Rd,ser} = \frac{0,8 W_{el} f_{yp}}{\gamma_{M6,ser}} \geq M_{Ed,ser}$
Contact bearing stress	$f_{H,Rd} = \frac{2,5 f_y}{\gamma_{M6,ser}} \geq \sigma_{H,Ed,ser}$ $\sigma_{H,Ed,ser} = 0,591 \sqrt{\frac{E F_{b,Ed,ser} (d_0 - d)}{d^2 t}}$
d diameter of pin; d_0 diameter of pin hole; f_y lower of yield strength of pin and connected part; f_{up} ultimate tensile strength of the pin; f_{yp} yield strength of pin; t thickness of connected part; A gross cross-sectional area of pin; W_{el} elastic section modulus of pin; $F_{b,Ed,ser}$ design value of force to be transferred in bearing, under the characteristic load combination for serviceability limit states.	

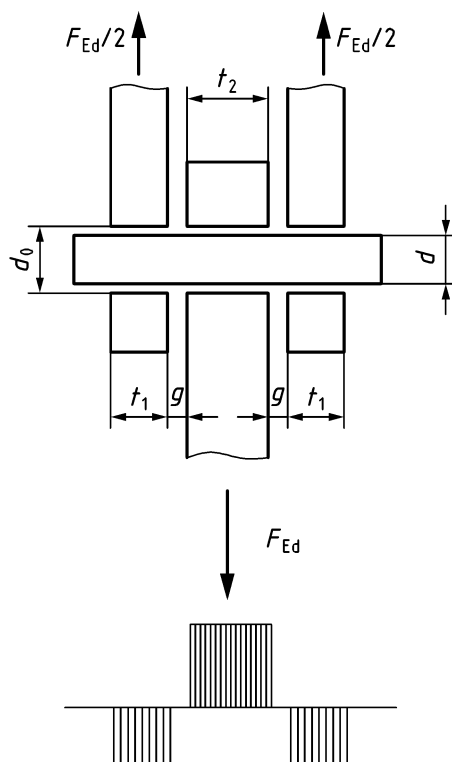


Figure 5.2 — Bending moment in a symmetrical pin connection with three connecting parts

5.7.4 Design criteria for riveted connections

- (1) The design criteria for shear connections should follow Table 5.7.
- (2) Where a tension force is present the design value of tension force $F_{t,Ed}$ should not be greater than the design tension resistance for rivets $F_{t,Rd}$ given in Table 5.9.
- (3) Rivets subjected to a combination of shear and tension force should also satisfy the criteria given in Table 5.9.

Table 5.7 — Design criteria for riveted connections

Shear connections
Design criteria at ultimate limit state: — The design value of bearing resistance $F_{b,Rd}$ should not be exceeded at any rivet hole. — The design value of shear resistance of a rivet $F_{v,Rd}$ should not be exceeded at any shear plane. Remarks: — $F_{v,Rd}$ and $F_{b,Rd}$ should be obtained from Table 5.9; — The design value of resistance of the connection should be obtained from 5.11.
The design value of ultimate resistance of the net cross-section considering holes should be verified according to 8.2.3(5) of EN 1993-1-1:2022.