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**Static design procedure for  
welded hollow-section joints —  
Recommendations**

*Procédure statique de conception des joints soudés à section creuse —  
Recommandations*

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Published in Switzerland

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## Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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

ISO 14346 was prepared by the International Institute of Welding, which has been approved as an international standardizing body in the field of welding by the ISO Council.

Requests for official interpretations of any aspect of this International Standard should be directed to the ISO Central Secretariat, who will forward them to the IAW Secretariat for an official response.

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# Static design procedure for welded hollow-section joints — Recommendations

## 1 Scope

This International Standard gives guidelines for the design and analysis of welded uniplanar and multiplanar joints in lattice structures composed of circular (CHS), square (SHS) or rectangular (RHS) hollow sections, and of uniplanar joints in lattice structures composed of combinations of hollow sections with open sections under static loading. This International Standard is applicable to CHS or RHS Y-, X- and K-joints and their multiplanar equivalents, gusset plate to CHS or RHS joints, open-section and RHS to CHS joints, and hollow-section to open-section joints.

## 2 Normative references

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

ISO 630 (all parts), *Structural steels*

ISO 14347, *Fatigue — Design procedure for welded hollow-section joints — Recommendations*

ISO/TR 25901, *Welding and related processes — Vocabulary*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14347, ISO/TR 25901, and the following apply.

### 3.1

#### **chord face failure**

#### **chord plastification**

plastic failure of the chord face or plastic failure of the chord cross-section

### 3.2

#### **chord punching shear**

crack initiation in a hollow-section chord wall leading to rupture of a brace member from the chord member

### 3.3

#### **chord side wall failure**

#### **chord web failure**

yielding, crushing or instability (crippling or buckling of the chord side wall or chord web) under the relevant brace member

### 3.4

#### **cross-section classification**

identification of the extent to which the resistance (to axial compression or bending moment) and rotation capacity of a cross-section are limited by its local buckling resistance

Note 1 to entry: For example, four classes are given in Eurocode 3 (see EN 1993-1-1) together with three limits on diameter-to-thickness ratio for CHS or width-to-thickness ratio for RHS.

**3.5  
joint configuration**

type or layout of the joint or joints in a zone within which the axes of two or more interconnected members or elements intersect

**3.6  
local chord member yielding**

local buckling of the chord connecting face in an overlapped joint

**3.7  
local yielding of overlapping brace  
local yielding of overlapping plate  
local yielding of brace  
local yielding of plate**

cracking in the weld or in a brace member, or local buckling of a brace member with reduced effective width

**3.8  
multiplanar joint**

in a lattice structure, a joint connecting members situated in more than one plane

**3.9  
structural properties of a joint**

resistance to forces and moments in the connected members, deformation and/or rotation capacity

**3.10  
uniplanar joint**

in a lattice structure, a joint connecting members situated in a single plane

**4 Symbols and abbreviated terms**

- $A_i$  cross-sectional area of member  $i$  ( $i = 0, 1, 2$ )
- $A_s$  shear area of a chord member
- $b_e$  effective width of a plate or RHS brace member
- $b_{ei}$  effective width of an overlapping RHS brace member at the chord connection
- $b_{ej}$  effective width of an overlapped RHS brace member at the chord connection
- $b_{e,ov}$  effective width of an overlapping RHS brace member at the overlapped brace connection
- $b_{e,p}$  effective width for punching shear
- $b_i$  overall out-of-plane width of a plate or RHS or I- or H-member  $i$  ( $i = 0, 1, 2$ )
- $b_w$  effective width for the web of an I- or H-section, or RHS side wall
- $C_1$  coefficient used in the chord stress function  $Q_f$  as shown in [Tables 2, 4, 6, and 9](#)
- $c$  coefficient defined in [Table 13](#)
- $c_s$  coefficient for effective shear area
- $d_e$  effective width of a CHS brace member
- $d_{ei}$  effective width of an overlapping CHS brace member at the chord connection
- $d_{ej}$  effective width of an overlapped CHS brace member at the chord connection

$d_{e,ov}$	effective width of an overlapping CHS brace member at the overlapped brace connection
$d_i$	overall diameter of CHS member $i$ ( $i = 0, 1, 2$ )
$d_w$	depth of the web of an I- or H-section chord member ( $d_w = h_0 - 2t_0 - 2r$ )
$e$	nodding eccentricity of a joint, shown in <a href="#">Figure 1 h</a> ), with a positive value of $e$ representing an offset from the chord centreline towards the outside of the truss
$F_{ax}$	axial force in a brace member
$F_{gap,0}^*$	design resistance for the axial force in a chord member at the gap location
$F_{gap,0}$	design value of the axial force in a chord member at the gap location
$F_i^*$	design resistance of the joint, expressed in terms of the axial force in member $i$ ( $i = 1, 2$ )
$F_i$	design value of the axial force in member $i$ ( $i = 0, 1, 2$ )
$F_{pl,0}$	axial yield capacity of a chord member
$F_s^*$	design resistance for the shear force of the brace to chord connection in an overlapped joint
$F_{s,gap,0}$	design value of the shear force in a chord member at the gap location
$F_{s,pl,0}$	shear yield capacity of a chord member
$F_{s,0}$	design value of the shear force in a chord member
$g$	gap between the brace members in a K- or N-joint, defined in <a href="#">Figure 1 h</a> )
$g_t$	transverse gap in KK-joints, defined in <a href="#">Figure 1 n</a> )
$h_i$	overall in-plane depth of a plate or RHS or I- or H-section member $i$ ( $i = 0, 1, 2$ )
$h_z$	distance between the centres of gravity of the effective parts of the brace (beam) as shown in <a href="#">Table 12</a>
$i$	integer subscript used to designate a member of a joint: 0 denotes a chord member; 1, 2 denote the brace members. In joints with two brace members, 1 normally denotes the compression brace and 2 the tension brace. For a single brace, $i = 1$ whether it is subject to compression or tension. For an overlap type joint, $i$ is the integer subscript to designate the overlapping brace
$j$	integer subscript used to designate the overlapped brace member in overlap type joints
$k_b$	factor defined in <a href="#">Table 3</a>
$\ell_{b,eff}$	effective perimeter for local yielding of the (overlapping) brace
$\ell_{p,eff}$	effective perimeter for chord punching shear
$M_i$	design value of the moment in member $i$ ( $i = 0, 1, 2$ )
$M_{ip,i}^*$	design resistance of the joint, expressed in terms of the in-plane moment in member $i$ ( $i = 1, 2$ )

$M_{ip,i}$	design value of the in-plane moment in member $i$ ( $i = 1, 2$ )
$M_{op,i}^*$	design resistance of the joint, expressed in terms of the out-of-plane moment in member $i$ ( $i = 1, 2$ )
$M_{op,i}$	design value of the out-of-plane moment in member $i$ ( $i = 1, 2$ )
$M_{pl,0}$	plastic moment capacity of a chord member
$n$	factor to account for chord stress in $Q_f$ function (see applicable table)
$O_v$	overlap ratio, expressed as a percentage $O_v = \frac{q}{p} \times 100\%$
$O_{v,limit}$	overlap limit for brace shear check
$p$	length of the projected contact area of the overlapping brace member onto the face of the chord, in the absence of the overlapped brace member, in a K- or N-joint, defined in <a href="#">Figure 1 i</a> )
$Q_f$	chord stress function as defined in <a href="#">Tables 2, 4, 6, and 9</a>
$Q_u$	function in the design resistance equation as defined in <a href="#">Tables 2, 3, 4, 6, 7, and 8</a>
$Q_{ub}$	function in the design resistance equation for brace bending as defined in <a href="#">Table 4</a>
$q$	length of overlap, measured at the face of the chord, between one brace member toe and the position of the other projected brace member toe, in a K- or N-joint, defined in <a href="#">Figure 1 i</a> )
$r$	fillet radius of an I- or H-section
$r_o$	external corner radius of an RHS
$t$	wall thickness
$t_i$	wall thickness (for CHS or RHS) or flange thickness (for I- or H-section) of member $i$ ( $i = 0, 1, 2$ )
$t_w$	web thickness of an I- or H-section
$W_{el,i}$	elastic section modulus of member $i$ ( $i = 0, 1, 2$ )
$W_{pl,i}$	plastic section modulus of member $i$ ( $i = 0, 1, 2$ )
$\alpha$	factor used in the expression of $A_s$ in <a href="#">Tables 6 and 11</a>
$\beta$	ratio of the mean diameter or width of the brace members, to that of the chord
for T, Y- and X-joints	$\beta = \frac{d_1}{d_0} \quad \text{or} \quad \frac{d_1}{b_0} \quad \text{or} \quad \frac{b_1}{b_0}$
for K- and N-joints	$\beta = \frac{d_1 + d_2}{2d_0} \quad \text{or} \quad \frac{b_1 + b_2}{2b_0} \quad \text{or} \quad \frac{b_1 + b_2 + h_1 + h_2}{4b_0}$
for plate to CHS	$\beta = \frac{b_1}{d_0}$

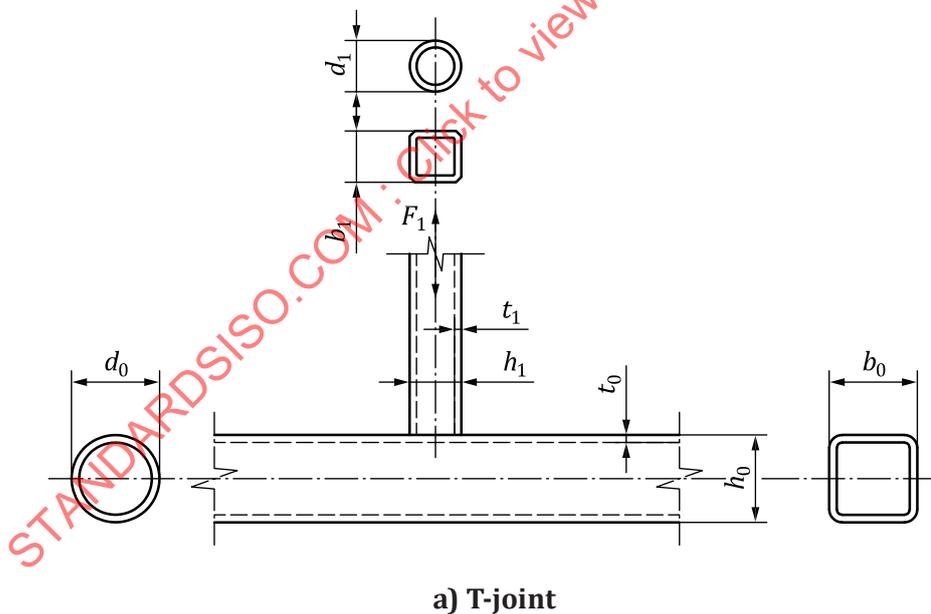
	for plate to RHS	$\beta = \frac{b_1}{b_0}$	
$\gamma$	ratio of the chord width or diameter to twice the chord thickness	$\gamma = \frac{d_0}{2t_0}$ or $\frac{b_0}{2t_0}$	
$\gamma_F$	partial load factor on applied loading		
$\gamma_M$	partial safety factor on joint resistance		
$\eta$	ratio of the brace member depth to the chord diameter or width	$\eta = \frac{h_1}{d_0}$ or $\frac{h_1}{b_0}$	
$\theta_i$	included angle between brace member $i$ and the chord ( $i = 1, 2$ )		
$\lambda$	slenderness		
$\mu$	multiplanar factor defined in <a href="#">Tables 5</a> and <a href="#">10</a>		
$\sigma_k$	design stress for chord side wall failure		
$\sigma_u$	ultimate tensile stress		
$\sigma_y$	yield stress		
$\sigma_{yi}$	yield stress of member $i$ ( $i = 0, 1, 2$ )		
$\phi$	angle between the planes in a multiplanar joint defined in <a href="#">Figures 1 j)</a> to <a href="#">o)</a> , or resistance factor		
$\chi$	reduction factor for (column) buckling		
CHS	circular hollow section		
RHS	rectangular hollow section		
SHS	square hollow section		

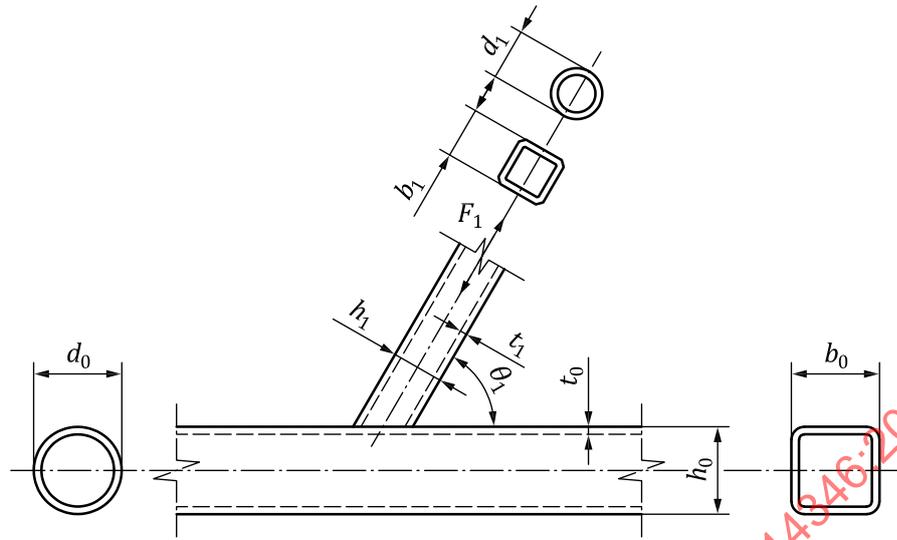
## 5 Requirements

The following conditions are requirements for hollow-section joints.

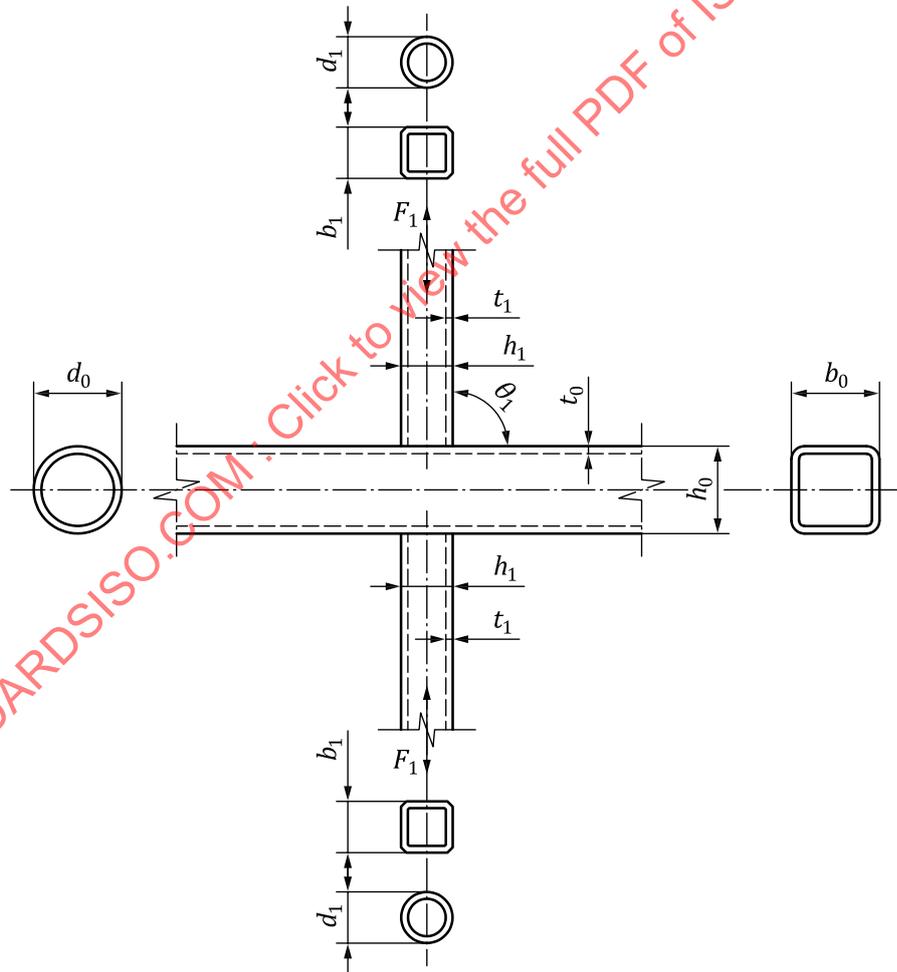
- Steel grades shall be according to [Clause 6](#).
- Hollow-section joint types shall be according to [Clause 7](#).
- The nominal wall thickness of hollow sections shall be limited to a minimum of 1,5 mm.
- For hollow-section chords with a wall thickness greater than 25 mm, the steel shall meet adequate through thickness properties as specified in ISO 630.
- The ends of members that meet at a joint shall be prepared in such a way that their cross-sectional shape is not modified. Flattened end joints and cropped end joints are not covered in this International Standard.
- Where brace members are welded to a chord member, the included angle between brace and chord ( $\theta_i$ ) should be at least 30°. This is to ensure that proper welds can be made. For angles less than 30°, confirmation that sound welds can be made should be obtained from the fabricator.

- In gap-type joints, to ensure that there is adequate clearance to form satisfactory welds, the gap between adjacent brace members shall not be less than the sum of the brace member thicknesses ( $t_1 + t_2$ ).
- In overlap-type joints, the overlap shall be large enough to ensure that the interconnection of the brace members is sufficient for adequate shear transfer from one brace to the other. In any case, the overlap ratio (defined in [Clause 4](#)) shall be at least 25 %.
- Where overlapping brace members are of different widths, the narrower member shall overlap the wider.
- Where overlapping brace members with the same width have different thicknesses and/or different strength grades, the member with the lowest  $t_i\sigma_{yi}$ -value shall overlap the other member.
- In gap and overlap K-joints, the noding eccentricity,  $e$ , shown in [Figure 1 h](#)) and i), produces a primary bending moment which requires consideration when designing truss members.
- In gap and overlap K-joints, restrictions are placed on the noding eccentricity,  $e$ , shown in [Figure 1 h](#)) and i). Within the specified limits ( $e \leq 0,25d_0$  or  $e \leq 0,25h_0$ ), the bending moment due to this eccentricity is taken into account, for its effect on joint resistance, in the  $Q_f$  term (a function to account for chord stress at the connection face). If the noding eccentricity,  $e$ , exceeds the limits in the previous sentence, the effect of the resulting bending moment on the joint resistance shall be taken into account by distributing part of the total eccentricity moment to the brace members. (In such cases, the joint resistance shall then be determined by checking the interaction of brace axial load and brace bending moment.)
- For joints with one (or both) chord end(s) not connected to other members, the chord shall be extended from the centre of the joint over a length of  $3,5d_0$  or  $3,5b_0$  or the end(s) shall be welded to a cap plate with a thickness of at least  $1,5t_0$  or 10 mm.

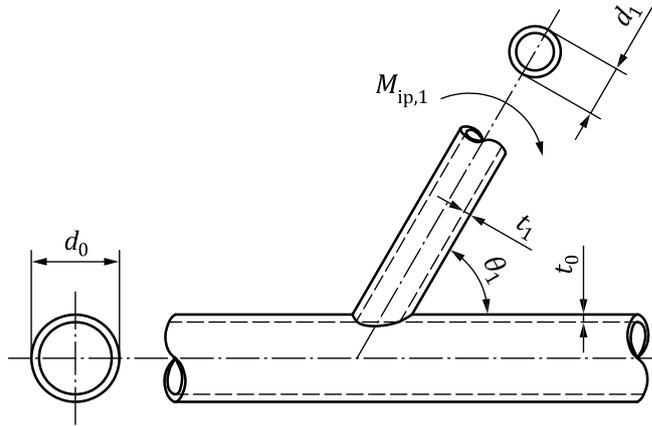




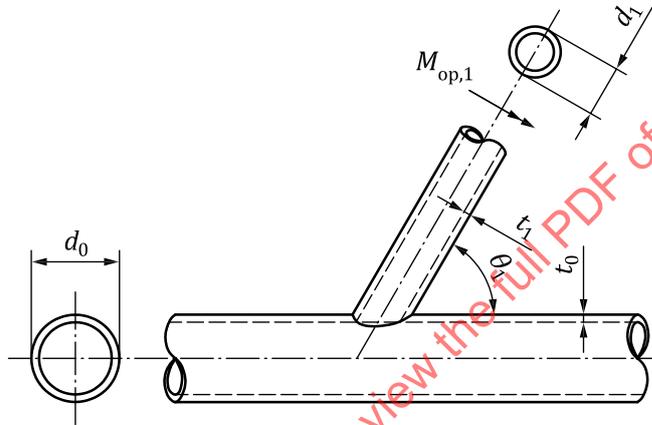
b) Y-joint



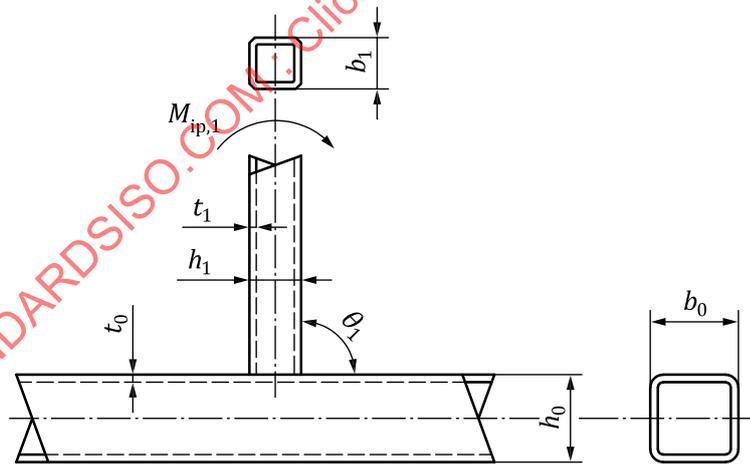
c) X-joint



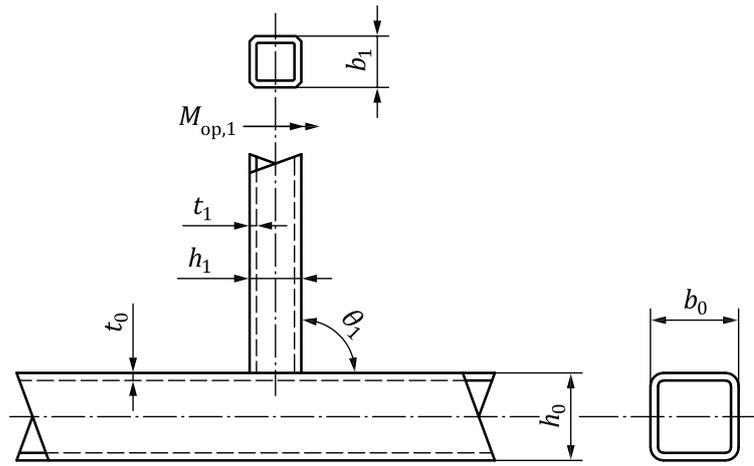
d) Y-joint (CHS chord) with brace in-plane bending



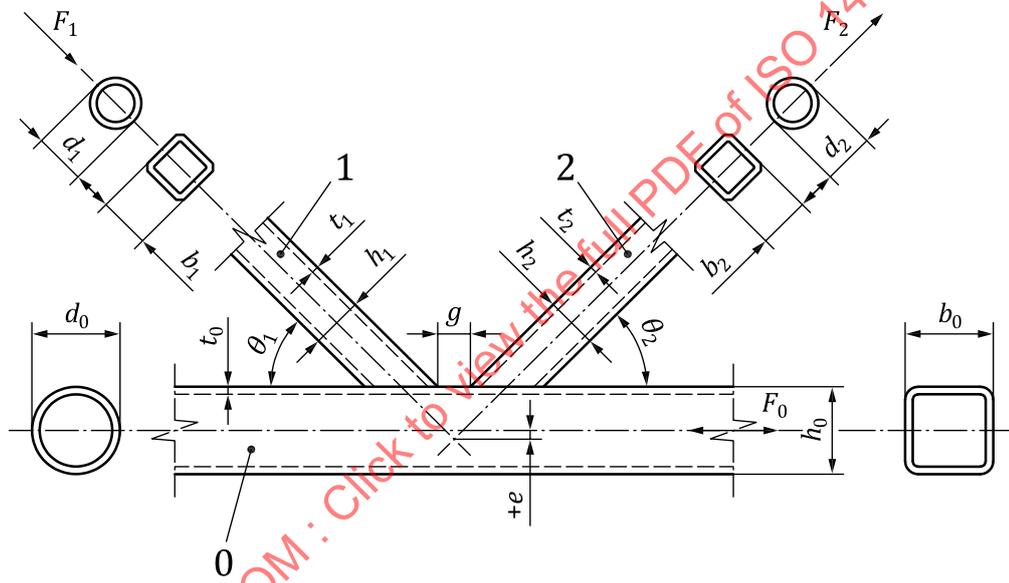
e) Y-joint (CHS chord) with brace out-of-plane bending



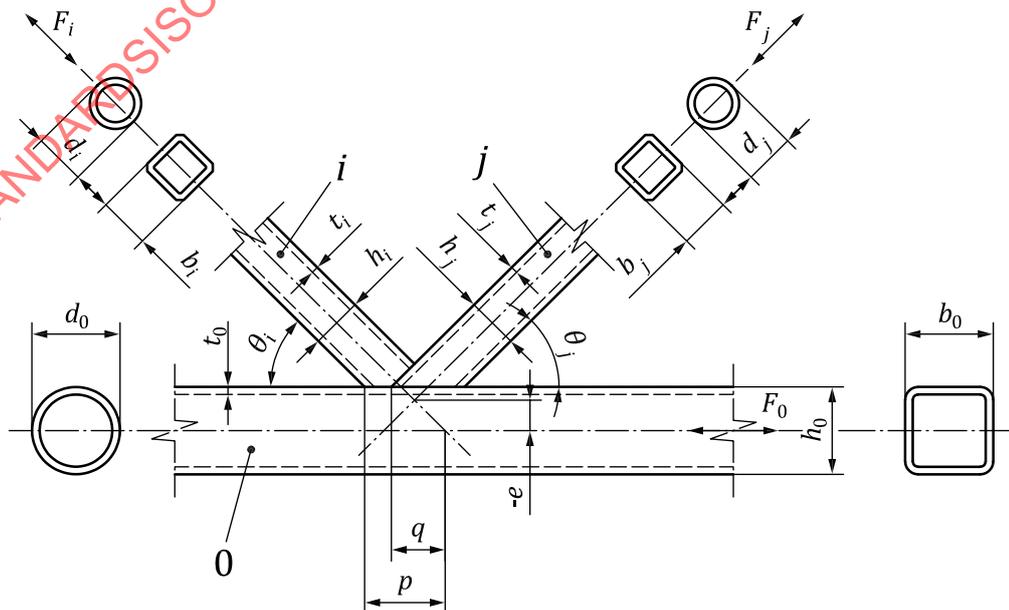
f) Y-joint (RHS chord) with brace in-plane bending



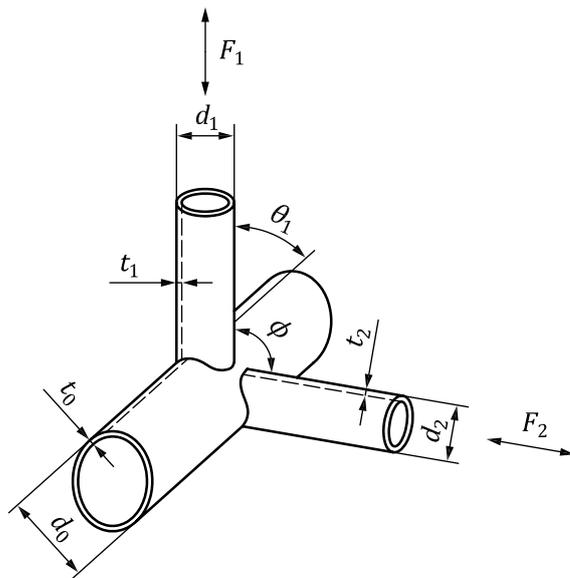
g) Y-joint (RHS chord) with brace out-of-plane bending



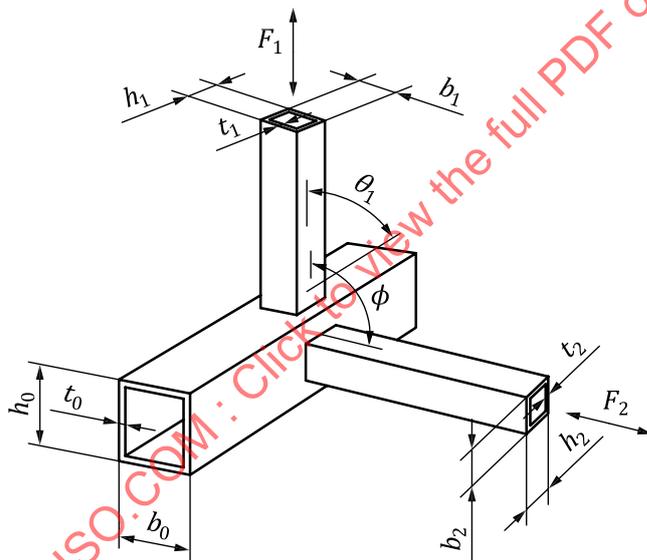
h) gap K-joint



i) overlap K-joint

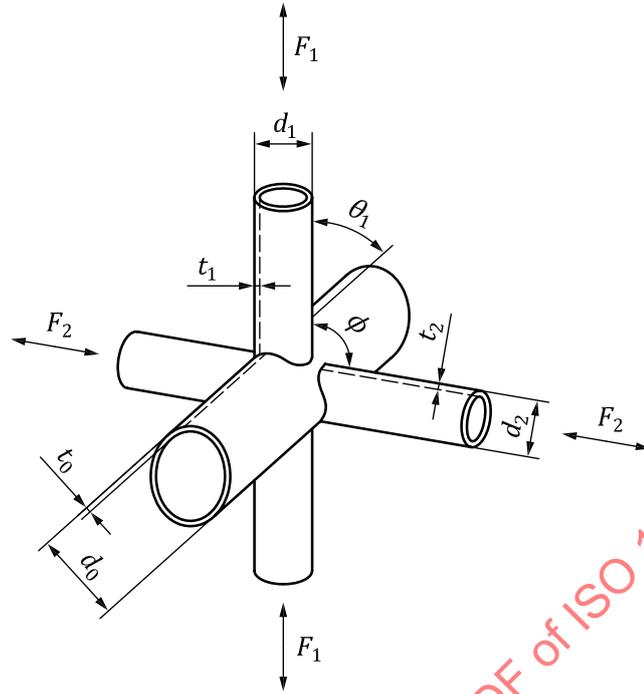


j) CHS TT-joint

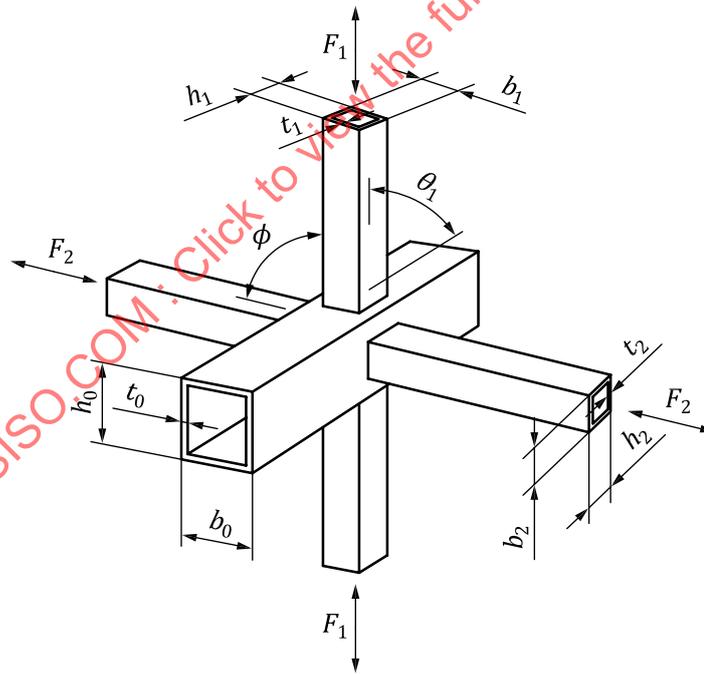


k) RHS TT-joint

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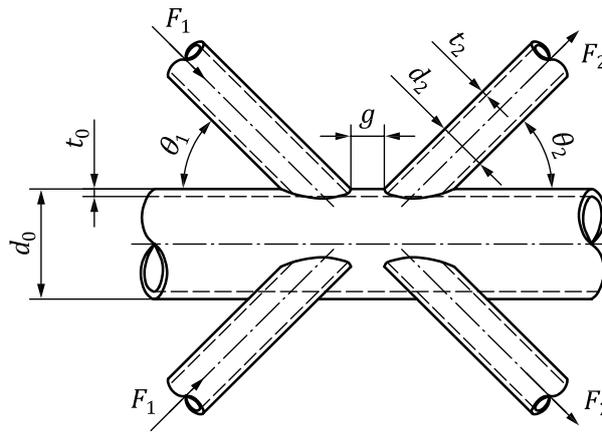
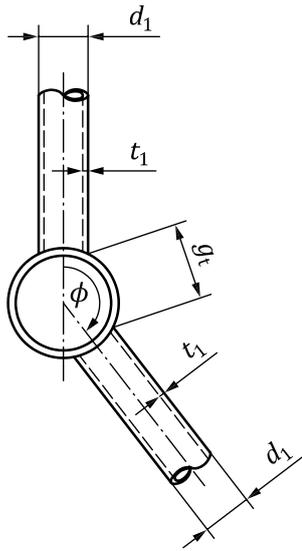


**l) CHS XX-joint**

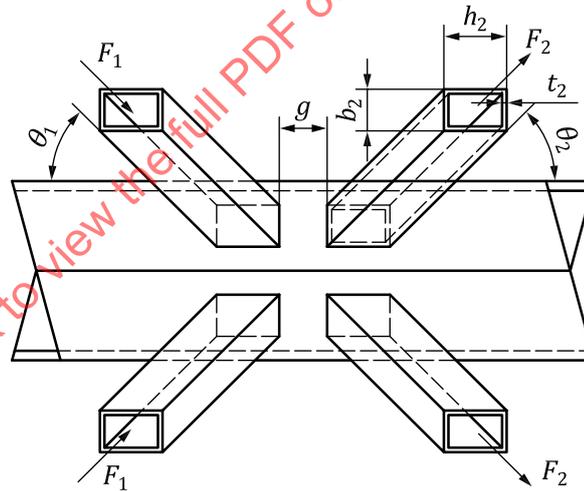
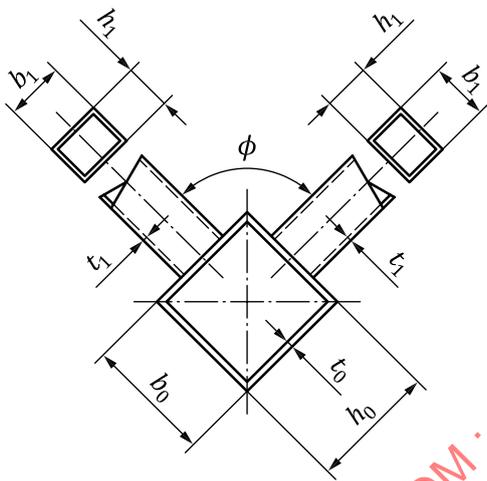


**m) RHS XX-joint**

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n) CHS gap KK-joint



o) RHS gap KK-joint

**Key**

- 0 chord
- 1 compression brace
- 2 tension brace
- i overlapping brace
- j overlapped brace

**Figure 1 — Joints between hollow sections**

**6 Materials**

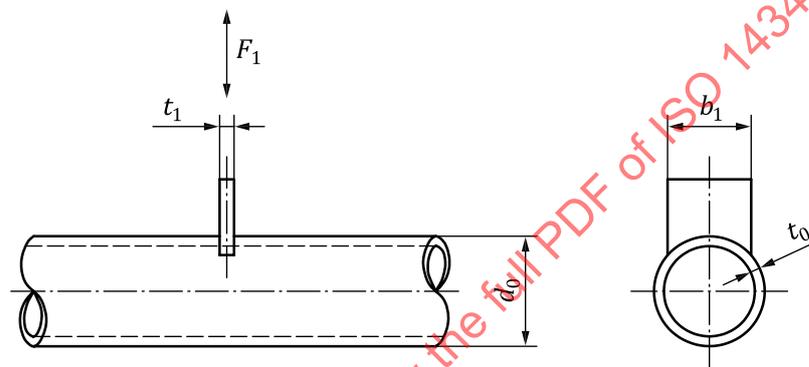
This International Standard is valid for both hot-finished (hot-formed) and cold-formed steel hollow sections. The manufactured hollow sections shall comply with the applicable national manufacturing specification for structural hollow sections. The nominal yield stress of hot-finished hollow sections and the nominal yield stress of the cold-formed hollow sections shall not exceed 460 N/mm<sup>2</sup> (MPa). Further criteria are given in 11.3. These nominal yield stresses pertain to the finished product, at the stipulated test locations.

## 7 Joint types

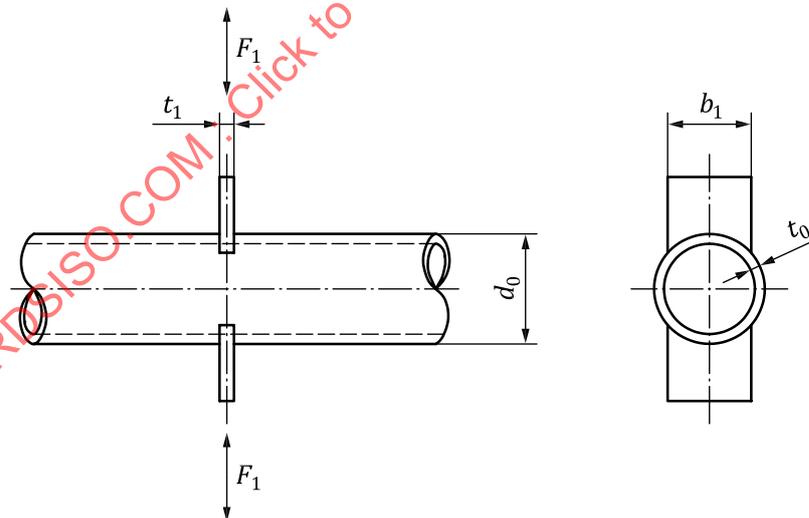
The joints covered in this International Standard consist of:

- CHS or RHS as used in uniplanar trusses or girders, such as Y- (with T- a special case thereof), X- and K- (with N- a special case thereof) joints (examples of which are given in [Figure 1](#)) and their multiplanar equivalents;
- gusset plate to CHS or RHS joints (examples of which are given in [Figure 2](#));
- open-section and RHS to CHS joints (examples of which are given in [Figure 3](#));
- hollow-section to open-section joints (examples of which are given in [Figure 4](#)).

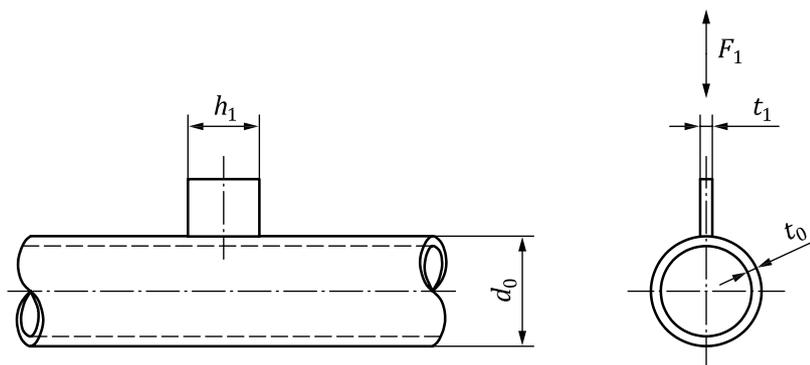
Geometric parameters for various joints are defined in [Figures 1](#) to [4](#). Recommended weld details for hollow-section joints are given in [Annex B](#).



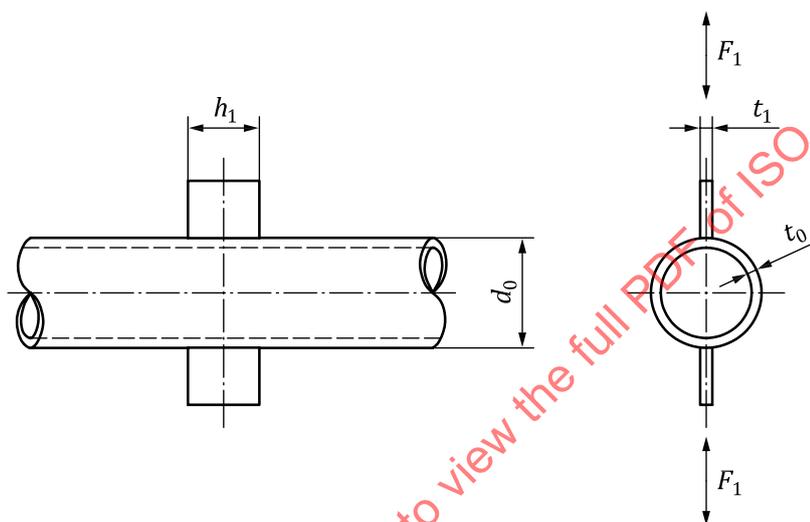
a) T-joint — transverse plate to CHS



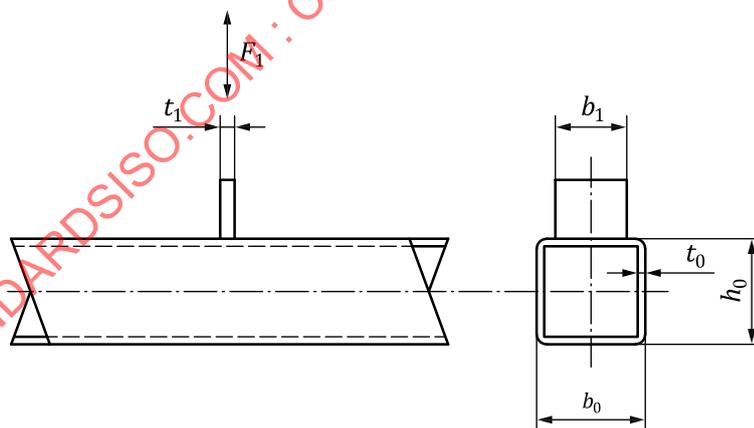
b) X-joint — transverse plate to CHS



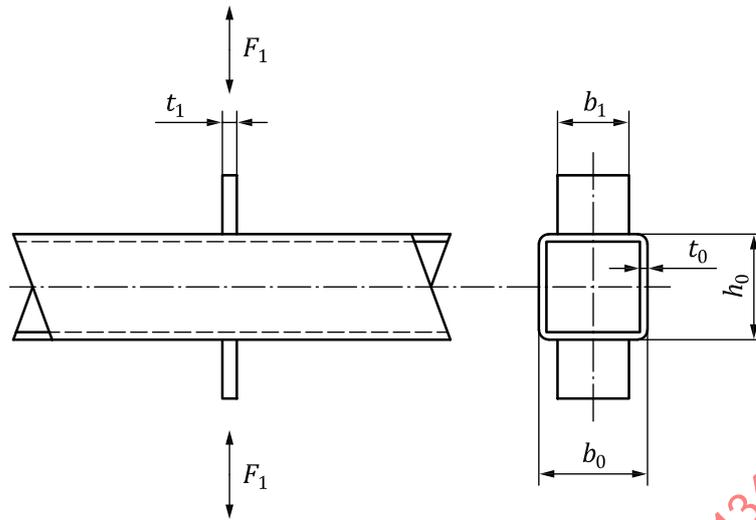
c) T-joint — longitudinal plate to CHS



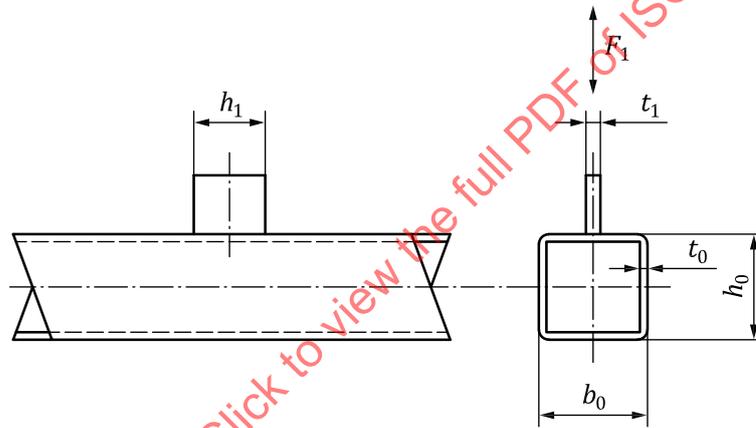
d) X-joint — longitudinal plate to CHS



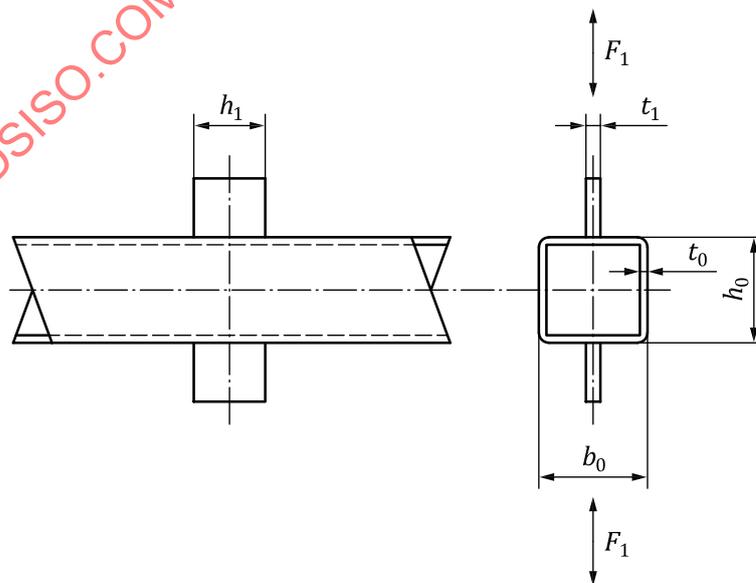
e) T-joint — transverse plate to RHS



f) X-joint — transverse plate to RHS

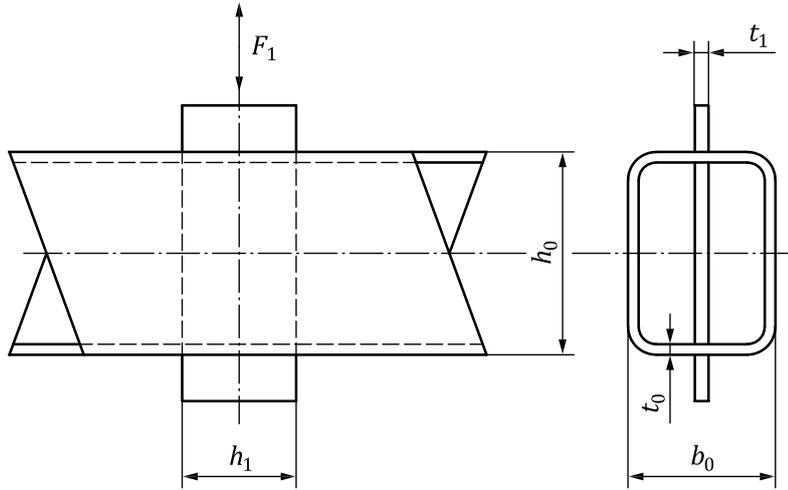


g) T-joint — longitudinal plate to RHS



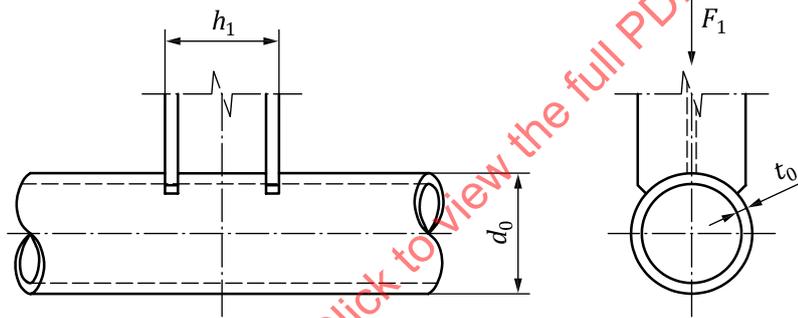
h) X-joint — longitudinal plate to RHS

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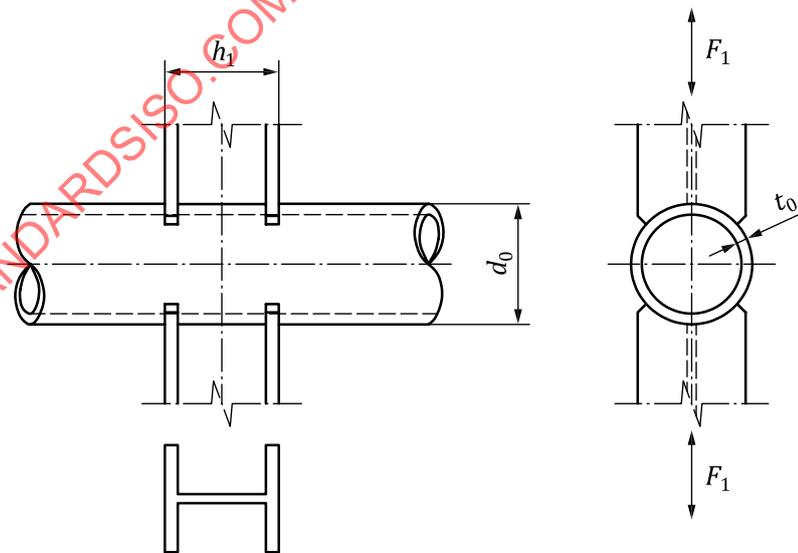


i) T-joint — longitudinal through plate to RHS

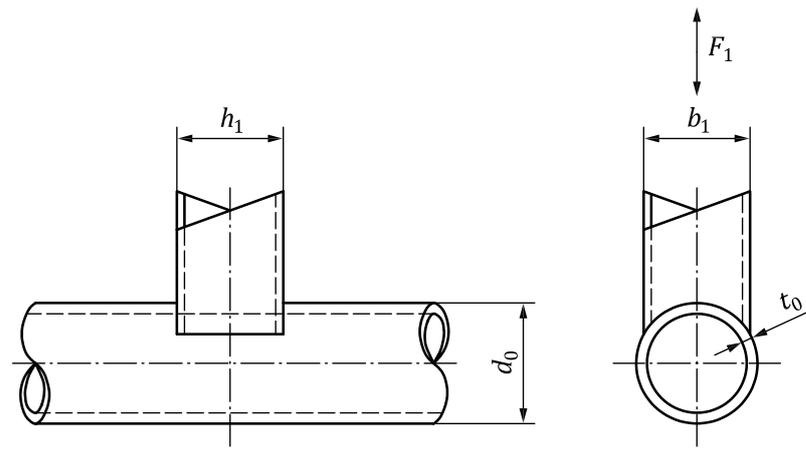
Figure 2 — Joints between gusset plates and CHS or RHS chords



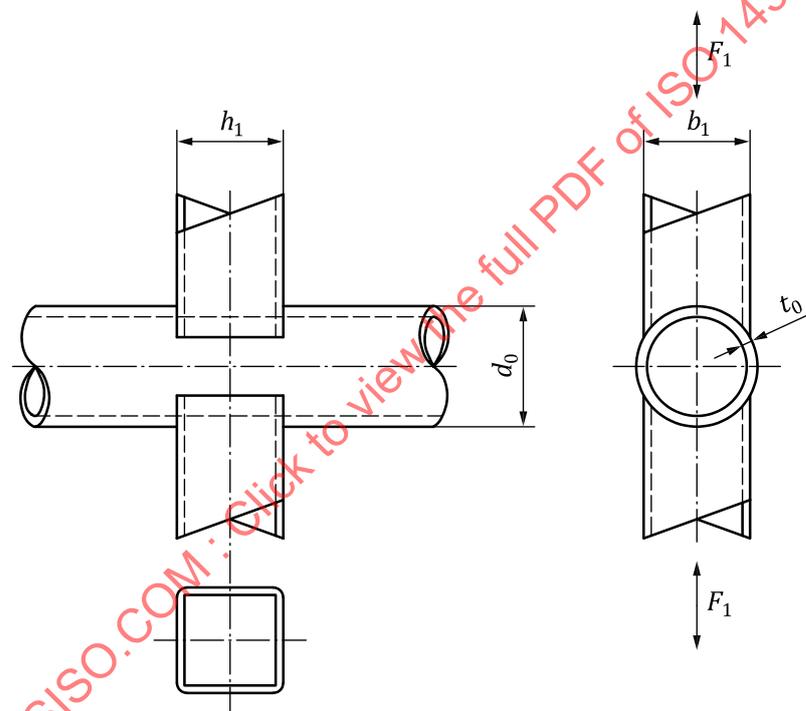
a) T-joint



b) X-joint

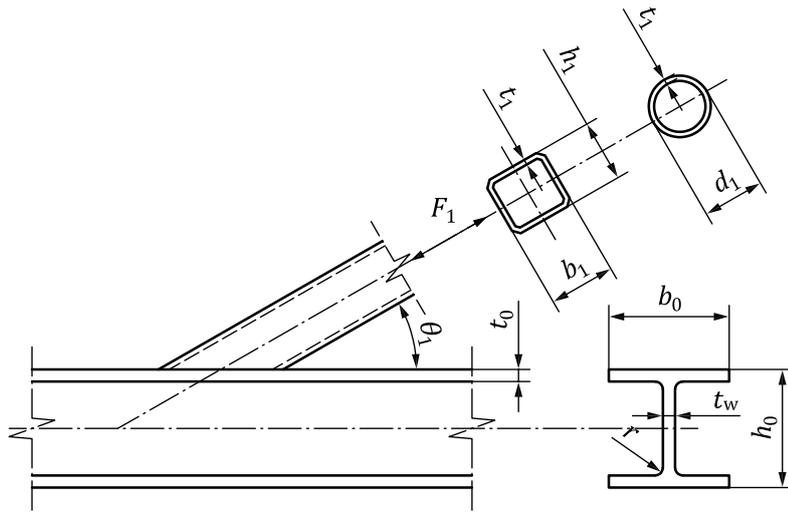


c) T-joint

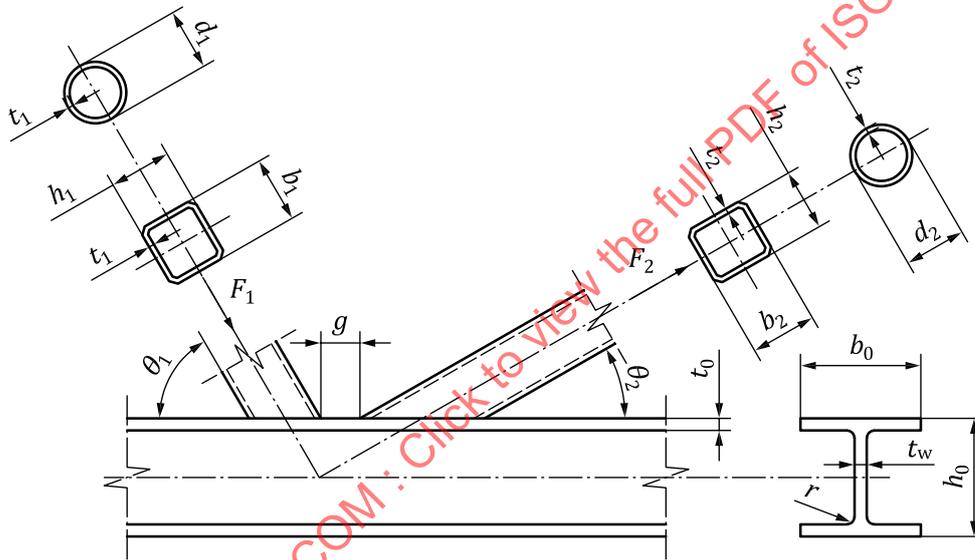


d) X-joint

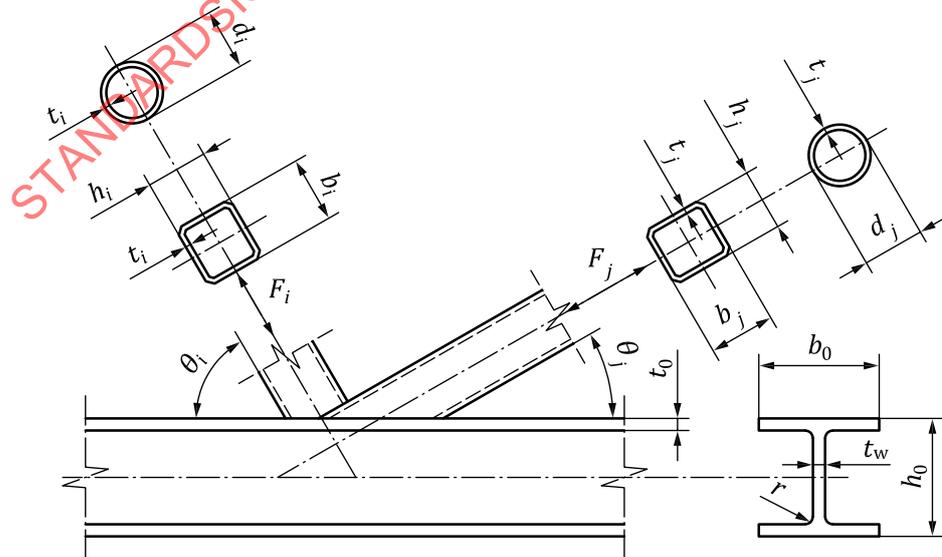
Figure 3 — Joints between open section or RHS braces and CHS chords



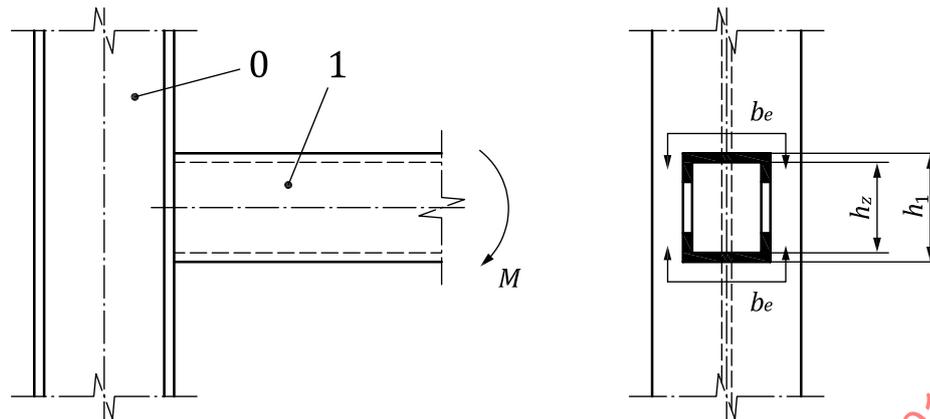
a) Y-joint



b) gap K-joint



c) overlap K-joint



d) T-joint subject to in-plane bending

**Key**

- 0 I- or H-section chord
- 1 RHS brace (beam)

**Figure 4 — Joints between CHS or RHS braces and open-section chords****8 Joint classification**

Hollow-section planar truss joints consist of one or more brace members that are directly welded to a continuous chord that passes through the joint. The classification of hollow-section truss-type joints as K- (which includes N-), Y- (which includes T-) or X-joints is based on the method of force transfer in the joint, not on the physical appearance of the joint. The joint types can be defined as follows.

- a) When the force component normal to the chord in a brace member ( $F_{ax}\sin\theta$ ) is equilibrated by beam shear in the chord member, the joint is classified as a T-joint when the brace is perpendicular to the chord, otherwise it is classified as a Y-joint.
- b) When the force component normal to the chord in a brace member ( $F_{ax}\sin\theta$ ) is essentially equilibrated (within 20 %) by loads in other brace member(s) on the same side of the joint, the joint is classified as a K-joint. The relevant gap is, in principle, between the primary brace members whose loads equilibrate. An N-joint is to be considered as a type of K-joint with one brace at  $90^\circ$ .
- c) When the force component normal to the chord ( $F_{ax}\sin\theta$ ) is transmitted through the chord member and is equilibrated by brace member(s) on the opposite side, the joint is classified as an X-joint.

Examples of such classification are shown in [Figure 5](#).

When brace members transmit part of their load as K-joints and part of their load as T-, Y-, or X-joints, the adequacy of each brace needs to be determined by linear interaction of the proportion of the brace load involved in each type of load transfer. One K-joint, in [Figure 5 b](#)), illustrates that the brace force components normal to the chord member may differ by as much as 20 % and still be deemed to exhibit K-joint behaviour. This is to accommodate slight variations in brace member forces along a typical truss, caused by a series of panel point loads. The N-joint in [Figure 5 c](#)), however, has a ratio of brace force components normal to the chord member of 2:1. That particular joint needs to be analysed as both a “pure” K-joint (with balanced brace forces) and an X-joint (because the remainder of the diagonal brace

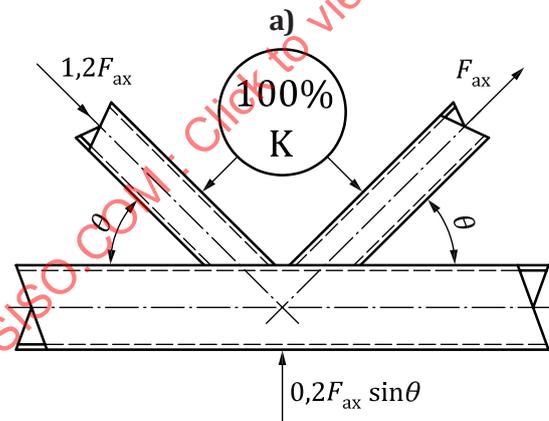
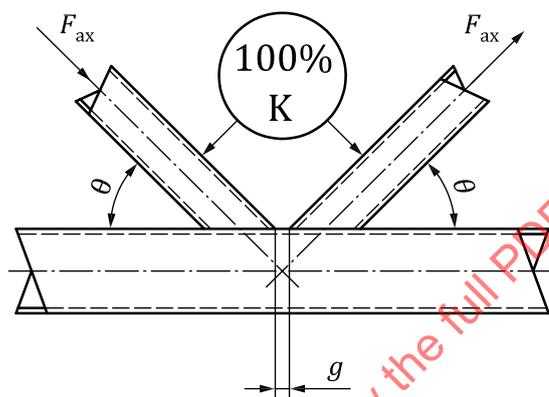
load is being transferred through the joint), as shown in [Figure 6](#). For the diagonal tension brace in that particular joint, one would need to check that:

$$\frac{0,5F_{ax}}{F_K^*} + \frac{0,5F_{ax}}{F_X^*} \leq 1,0$$

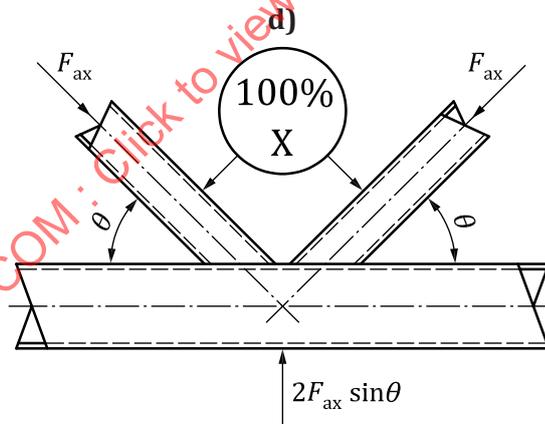
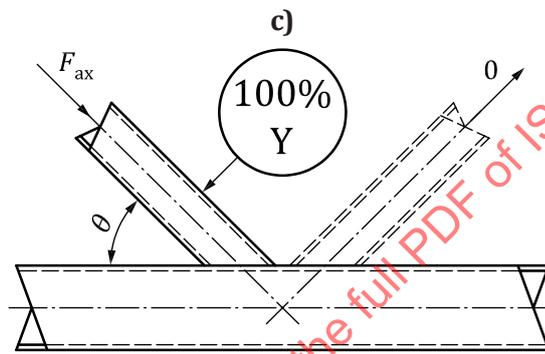
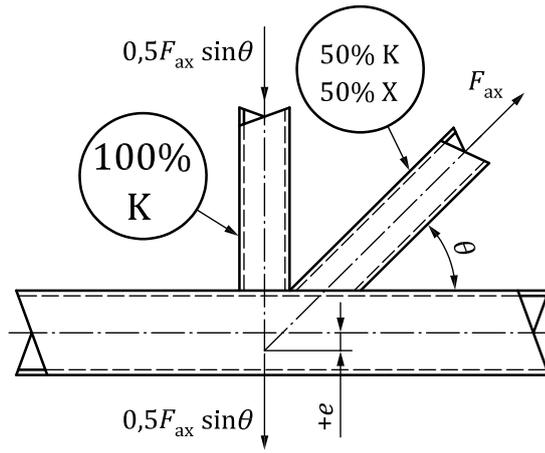
where

$F_K^*$  is the resistance of a K-joint;

$F_X^*$  is the resistance of an X-joint.

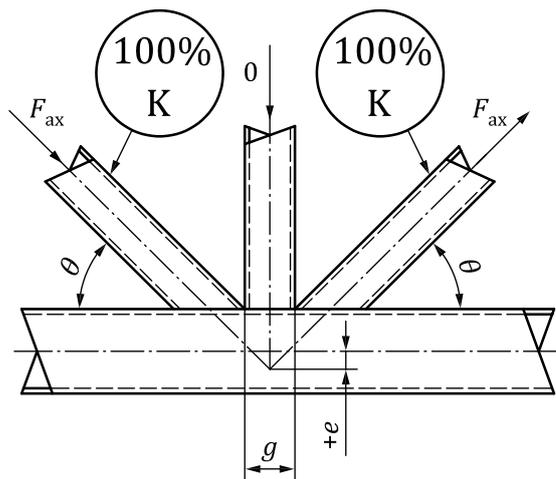


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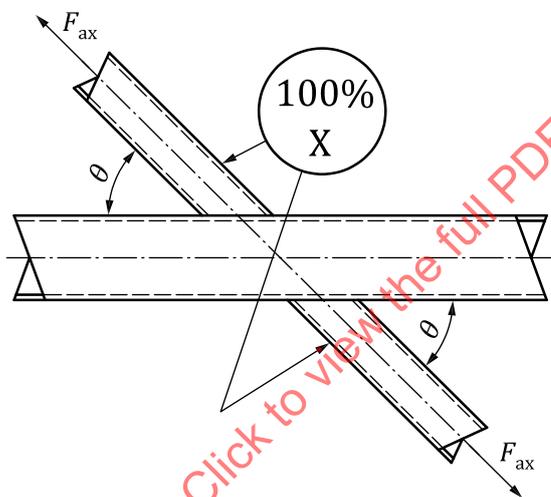


e)

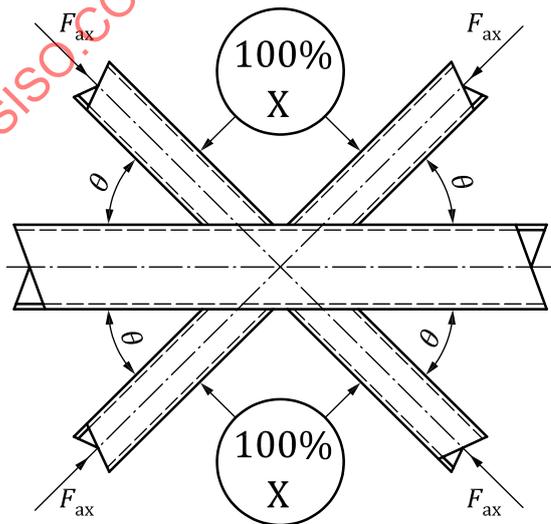
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f)



g)



h)

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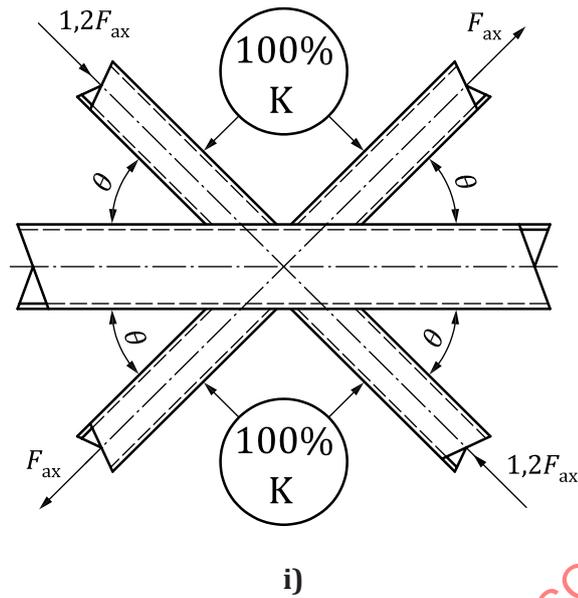


Figure 5 — Examples of hollow-section joint classification

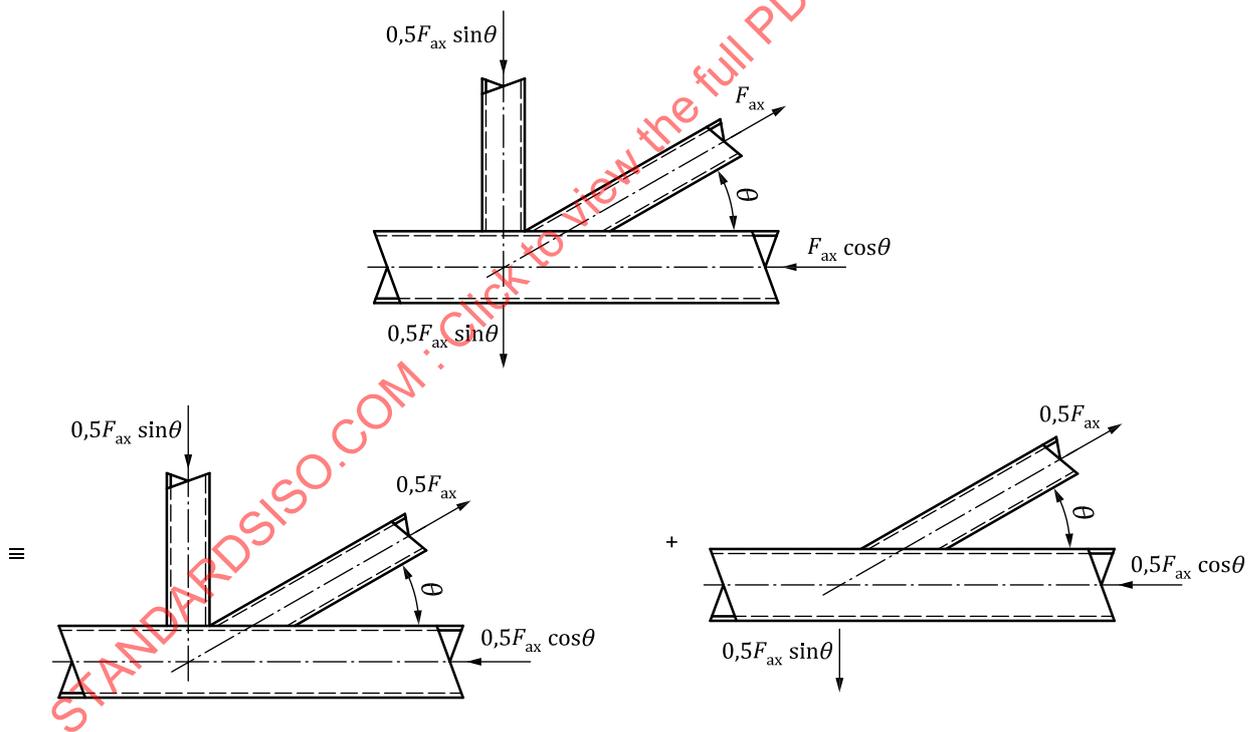


Figure 6 — Checking of an N-joint with unbalanced brace member loads

## 9 Limit states design

The design methodology used herein is a limit states design (LSD) procedure, also called a load and resistance factor design (LRFD) procedure. All loads are considered to be factored loads and the factored load effect must not exceed the design resistance, where the design resistance is based on an ultimate

limit state (or states) corresponding to the maximum load carrying capacity or the load at a maximum deformation limit.

NOTE In the analyses for the determination of the design strengths, the assumed mean values and coefficients of variation for the dimensional, geometric and mechanical properties are listed in [Table 1](#).

**Table 1 — Mean values and coefficients of variation for the dimensional, geometric and mechanical properties**

Parameter (actual measured/specified nominal ratio)	Mean value	Coefficient of variation	Effect
CHS or RHS thickness, $t_i$	1,0	0,05	Important
CHS diameter, $d_i$ , or RHS width, $b_i$ , or depth, $h_i$	1,0	0,005	Negligible
Angle, $\theta_i$	1,0	1°	Negligible
Relative gap, $g' = g/t_0$	1,0	0,06	Important
Relative chord stress parameter, $n$	1,0	0,05	Important
Yield stress, $\sigma_y$	1,18	0,075	Important
Mean values or tolerances considerably deviating from these values can affect the resulting design value.			

## 10 Partial load and safety factors for loads and resistances

**10.1** The partial load factors for applied loading, for the ultimate ( $\gamma_F$ ) limit state, shall be taken from the relevant building code or specification being used.

**10.2** Partial safety factors ( $\gamma_M$ ) or resistance factors ( $\phi$ ) for hollow-section joints have already been incorporated into the design resistance formulae given in [Clauses 14 to 22](#). For informational purposes, the partial safety factors used in the various joint resistance formulae are given in [Table C.1](#).

## 11 Static design procedures

### 11.1 General

The static design procedures can be summarized as the following three steps:

- a) Step one: determine the design member forces in the brace(s) and chord;
- b) Step two: determine the design resistance of the joint;
- c) Step three: apply design criteria to assess if the joint resistance is sufficient.

### 11.2 Design member forces

The design member forces shall be determined using [Clause 12](#).

### 11.3 Design resistance

The design resistance for various types of joints is given in [Clauses 14 to 22](#), where the partial safety factors listed in [Table C.1](#) have already been incorporated. For material with a nominal yield stress ( $\sigma_y$ ) exceeding 355 N/mm<sup>2</sup>, the joint resistances specified in this International Standard shall be multiplied by 0,9. In addition, if the nominal yield stress exceeds 0,8 of the nominal ultimate stress ( $\sigma_u$ ) then the design yield stress shall be taken as 0,8 $\sigma_u$ .

## 11.4 Design criteria

The design member forces determined in 11.2 shall not exceed the design resistance given in 11.3 as appropriate. The design criteria are given in Clause 13.

## 12 Design member forces

### 12.1 Analysis methods

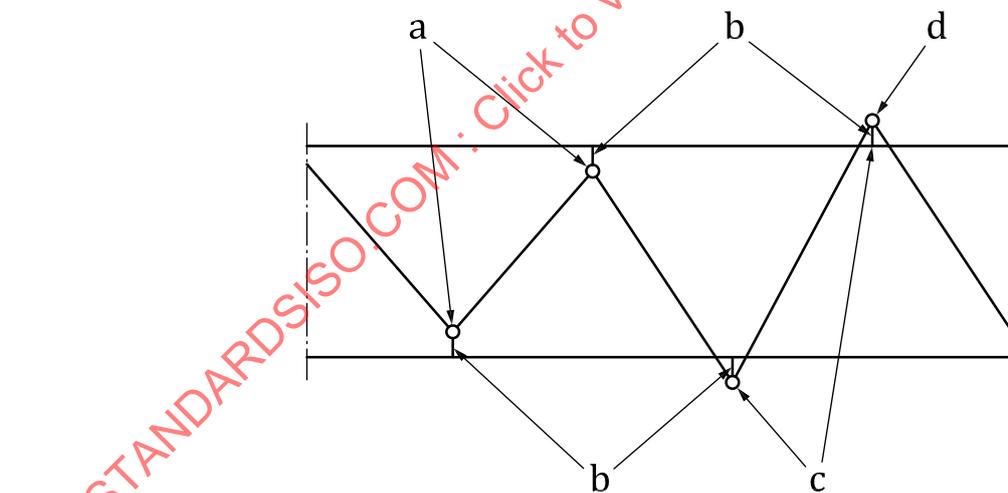
**12.1.1** For welded hollow-section structures, design member forces require determination by analysis of the complete structure, in which nodal eccentricity of the member centrelines at the joint is taken into account.

**12.1.2** Simplified analysis methods are acceptable for triangulated trusses or lattice girders with eccentricities  $e \leq 0,25d_0$  or  $e \leq 0,25h_0$  for gap and overlap K-joints; these are as follows.

- Pin-jointed analysis. Moments due to eccentricity need to be taken into account for the design of chords.
- Continuous chords with pin-ended braces. Axial forces and bending moments in the members can be determined using a structural analysis assuming a continuous chord and pin-ended braces (see Figure 7). This produces axial forces in the braces, and both axial forces and bending moments in the chord. This modelling assumption is particularly appropriate for loads on the chord members which are away from the node points or panel points.

**12.1.3** Rigid frame analysis shall be used for two- or three-dimensional Vierendeel girders.

**12.1.4** Other rational analysis procedures consistent with the joint stiffnesses may be used.



#### Key

- a noding condition for most overlap connections
- b extremely stiff members
- c noding condition for most gap connections
- d pin

**Figure 7 — Possible frame modelling assumption**

## 12.2 Design member forces

The following design member forces can be determined from [12.1](#):

- $F_i$  design axial force in the chord ( $i = 0$ ) or in the brace ( $i = 1, 2$ );
- $F_{s,0}$  design shear force in the chord;
- $M_{ip,i}$  design in-plane moment in the brace ( $i = 1, 2$ );
- $M_{op,i}$  design out-of-plane moment in the brace ( $i = 1, 2$ );
- $M_0$  design moment in the chord.

## 13 Design criteria

### 13.1 Failure modes

The design resistance of joints mentioned in [11.3](#) shall be based on the following failure modes as applicable:

- a) chord face failure or chord plastification;
- b) chord side wall failure (or chord web failure);
- c) chord shear;
- i) chord punching shear;
- j) local yielding of (overlapping) brace (or plate);
- f) local chord member yielding;
- g) brace shear.

These failure mode descriptions are used in [Tables 2](#) to [15](#), which list design resistances. Weld failure shall be avoided.

### 13.2 Uniplanar joints

#### 13.2.1 General

For joint types described in [Clauses 14, 15, 17, 18, 19, 21](#) and [22](#), the following design criteria apply.

- a) For joints within the range of validity given in [Tables 2](#) to [15](#), only failure modes listed in the resistance tables need to be considered. The design resistance of a joint shall be taken as the minimum value for these criteria.
- b) For joints outside the range of validity mentioned in a), all criteria given in [13.1](#) shall be considered.
- c) In joints with the brace member(s) subject only to axial forces, the design axial force  $F_i$  shall not exceed the design axial resistance of the welded joint  $F_i^*$ , expressed as an axial force in the brace member.

#### 13.2.2 Uniplanar joints with CHS chord

The following design criteria apply:

- a) for overlap joints, see [13.3](#);
- b) for special uniplanar joints with braces on both sides of the chord, see [13.4](#);

- c) In joints with the brace member(s) subjected to combined bending and axial forces, apply the following:

$$\frac{F_i}{F_i^*} + \left( \frac{M_{ip,i}}{M_{ip,i}^*} \right)^2 + \frac{M_{op,i}}{M_{op,i}^*} \leq 1,0$$

where

$F_i$ ,  $M_{ip,i}$ , and  $M_{op,i}$  are member forces determined in [Clause 12](#);

$F_i^*$ ,  $M_{ip,i}^*$  and  $M_{op,i}^*$  are design resistances determined in [Clauses 14](#) and [15](#).

### 13.2.3 Uniplanar joints with RHS chord

The following design criteria apply:

- a) for overlap joints, see [13.3](#);
- b) for special uniplanar joints with braces on both sides of the chord, see [13.4](#);
- c) for welded T-, Y-, X-, and gap K-joints between SHS or CHS brace members and SHS chord members only, where the geometry of the joints is within the range of validity given in [Table 6](#) and also satisfies the additional conditions given in [Table 8](#), the only consideration is chord plastification;
- d) in joints with the brace member(s) subjected to a combination of bending and axial forces, the following design criterion applies:

$$\frac{F_i}{F_i^*} + \frac{M_{ip,i}}{M_{ip,i}^*} + \frac{M_{op,i}}{M_{op,i}^*} \leq 1,0$$

where

$F_i$ ,  $M_{ip,i}$ , and  $M_{op,i}$  are member forces determined in [Clause 12](#);

$F_i^*$ ,  $M_{ip,i}^*$  and  $M_{op,i}^*$  are design resistances determined in [Clauses 17](#) and [18](#).

### 13.2.4 Uniplanar joints with CHS or RHS brace to I- or H-section chord

The following design criteria apply:

- a) for overlap joints, see [13.3](#);
- b) in joints with the brace member(s) subjected to a combination of in-plane bending and axial forces, the following applies:

$$\frac{F_i}{F_i^*} + \frac{M_{ip,i}}{M_{ip,i}^*} \leq 1,0$$

where

$F_i$  and  $M_{ip,i}$  are member forces determined in [Clause 12](#);

$F_i^*$  and  $M_{ip,i}^*$  are design resistances determined in [Clause 21](#).

### 13.3 Uniplanar overlap joints with a CHS, RHS, I- or H-section chord

Requirements are:

- a) the design axial forces in overlap joints shall not exceed the design axial resistances given in [Tables 13](#) and [14](#);
- b) the local yielding of the overlapping brace criterion and the local chord yielding criterion in [Table 13](#) always apply;
- c) the brace shear criterion in [Table 14](#) should only be checked if  $O_v > O_{v,limit}$ :  
 $O_{v,limit} = 60\%$  if the hidden seam of the overlapped brace is not welded,  
 $O_{v,limit} = 80\%$  if the hidden seam of the overlapped brace is welded.

For overlap joints with  $h_i < b_i$  and/or  $h_j < b_j$ , the brace shear criterion shall always be checked.

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### 13.4 Special uniplanar joints

The design resistance of several types of special uniplanar joints shown in [Figure 8 a\) to d\)](#), which are not dealt with in [13.2](#) and [13.3](#), can be directly related to that of the basic types (i.e. X and K).

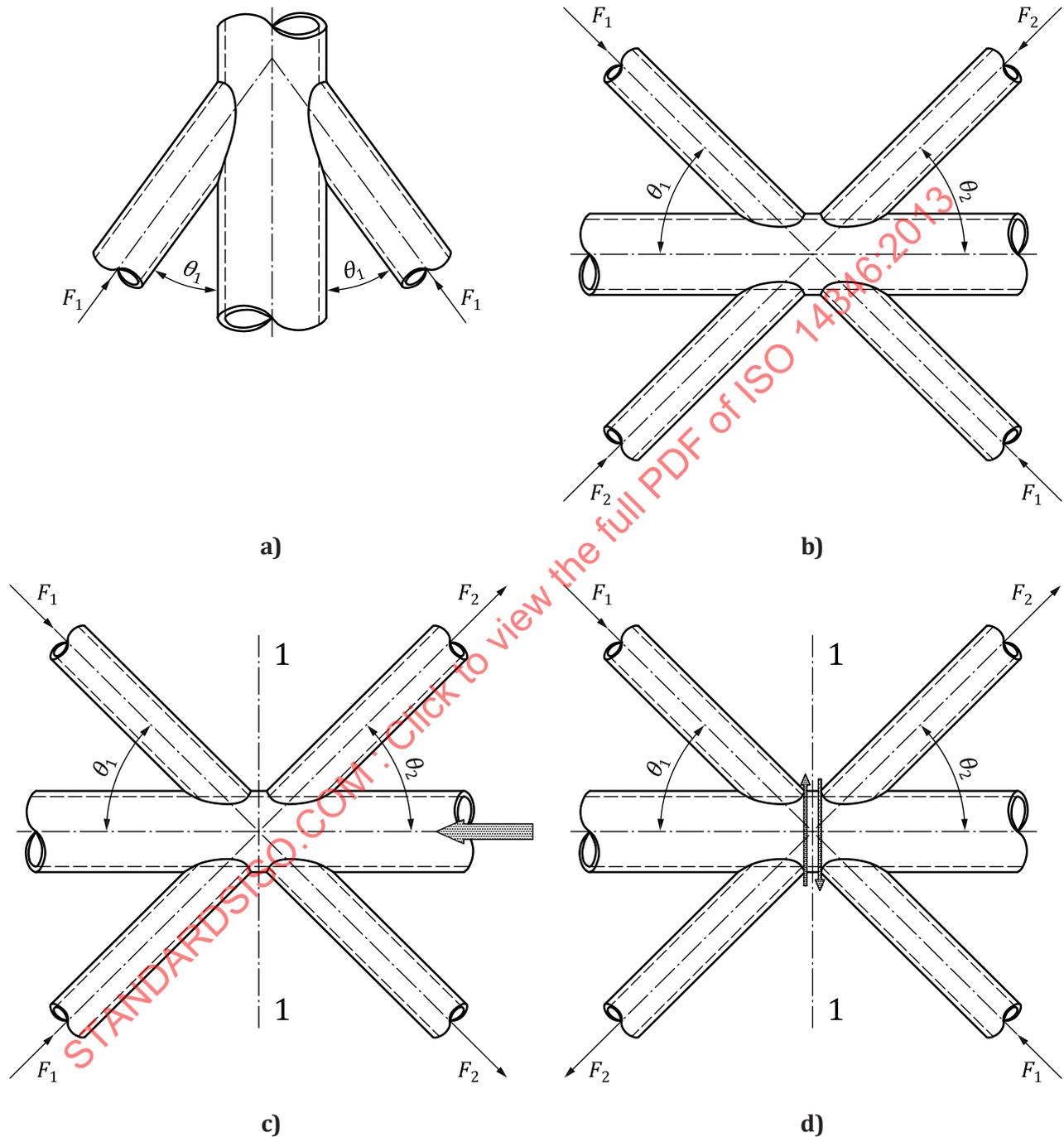


Figure 8 — Special types of uniplanar joints

The following criteria apply:

- a) in the joint in [Figure 8 a\)](#),  $F_1 \leq F_1^*$ , in which  $F_1^*$  is the design resistance of an X-joint given in [Table 2](#) or [Table 6](#);

- b) in the joint in [Figure 8 b](#)),  $F_1 \sin \theta_1 + F_2 \sin \theta_2 \leq F_i^* \sin \theta_i$ , in which  $F_i^*$  is the design resistance of an X-joint given in [Table 2](#) or [Table 6](#), where  $F_i^* \sin \theta_i$  is the larger of  $F_1^* \sin \theta_1$  and  $F_2^* \sin \theta_2$ ;
- c) in the joint in [Figure 8 c](#)),  $F_1 \leq F_1^*$  and  $F_2 \leq F_2^*$ , in which  $F_1^*$  and  $F_2^*$  are the design resistances of a K-joint, given in [Table 2](#) or [Table 6](#) — the force in the chord is the total chord force;
- d) in the joint in [Figure 8 d](#)),  $F_1 \leq F_1^*$  and  $F_2 \leq F_2^*$ , in which  $F_1^*$  and  $F_2^*$  are the design resistances of a K-joint, given in [Table 2](#) or [Table 6](#).

Further, the following chord shear criteria apply at [section 1-1](#) in [Figure 8 d](#)).

For CHS gap joints:

$$\left( \frac{F_{\text{gap},0}}{F_{\text{pl},0}} \right)^2 + \left( \frac{F_{\text{s,gap},0}}{F_{\text{s,pl},0}} \right)^2 \leq 1,0$$

in which  $F_{\text{gap},0}$  is the design value of the axial force in the chord,  $F_{\text{s,gap},0}$  is the design value of the shear force in the chord, both at the gap location.  $F_{\text{pl},0}$  is the axial yield capacity of the chord, i.e.  $F_{\text{pl},0} = A_0 \sigma_{y0}$ ,

and  $F_{\text{s,pl},0}$  is the shear yield capacity of the chord, i.e.  $F_{\text{s,pl},0} = 0,58 \sigma_{y0} \frac{2A_0}{\pi}$

For gap joints with an RHS chord or an I- or H-section chord:

$$F_{\text{s,gap},0} \leq F_{\text{s,pl},0} = 0,58 \sigma_{y0} A_s \text{ and } F_{\text{gap},0} \leq F_{\text{gap},0}^* = (A_0 - A_s) \sigma_{y0} + A_s \sigma_{y0} \sqrt{1 - \left( \frac{F_{\text{s,gap},0}}{F_{\text{s,pl},0}} \right)^2}$$

in which  $A_s$  is given in [Table 6](#) for RHS chord joints, and [Table 11](#) for I- or H-section chord joints.

## 13.5 Multiplanar joints

### 13.5.1 Multiplanar joints with CHS chord

For multiplanar joints with CHS chord, as described in [Clause 16](#), the following design criteria apply.

In each relevant plane of a multiplanar joint, the design criteria given in [13.2.1](#) and [13.2.2](#) shall be satisfied using the design resistance with the multiplanar factors given in [Table 5](#).

### 13.5.2 Multiplanar joints with RHS chord

For multiplanar joints with RHS chord, as described in [Clause 20](#), the following design criteria apply.

In each relevant plane of a multiplanar joint, the design criteria given in [13.2.1](#) and [13.2.3](#) shall be satisfied using the design resistance with the multiplanar factors given in [Table 10](#).

## 14 Design resistance of uniplanar CHS braces to CHS chord joints

### 14.1 Design axial resistance

The design axial resistance of uniplanar CHS to CHS joints shall be determined using [Table 2](#).

Table 2 — Design axial resistance of uniplanar CHS braces to CHS chord joints

Limit state		Axially loaded joints with CHS braces and chord		
Chord plastification		$F_i^* = Q_u Q_f \frac{\sigma_{y0} t_0^2}{\sin \theta_i}$		
Chord punching shear (for $d_i \leq d_0 - 2t_0$ )		$F_i^* = 0,58 \sigma_{y0} \pi d_i t_0 \frac{1 + \sin \theta_i}{2 \sin^2 \theta_i}$		
<b>Function <math>Q_u</math></b>				
T- and Y-joints See <a href="#">Figure 1 a</a> ) and <a href="#">Figure 1 b</a> )		$Q_u = 2,6(1 + 6,8\beta^2)\gamma^{0,2}$		
X-joints <sup>a</sup> See <a href="#">Figure 1 c</a> )		$Q_u = 2,6\left(\frac{1 + \beta}{1 - 0,7\beta}\right)\gamma^{0,15}$		
Gap K-joints See <a href="#">Figure 1 h</a> )		$Q_u = 1,65(1 + 8\beta^{1,6})\gamma^{0,3}\left[1 + \frac{1}{1,2 + (g/t_0)^{0,8}}\right]$		
<b>Function <math>Q_f</math></b>				
		$Q_f = (1 -  n )^{C_1}$		$n = \frac{F_0}{F_{pl,0}} + \frac{M_0}{M_{pl,0}}$ in connecting face
		Chord compression stress ( $n < 0$ )		Chord tension stress ( $n \geq 0$ )
T-, Y- and X-joints		$C_1 = 0,45 - 0,25\beta$		$C_1 = 0,20$
Gap K-joints		$C_1 = 0,25$		
<b>Range of validity</b>				
General		$0,2 \leq d_i/d_0 \leq 1,0$	$e/d_0 \leq 0,25$	$g \geq t_1 + t_2$
		$\theta_i \geq 30^\circ$	$\sigma_{yi} \leq \sigma_{y0}$ and $\sigma_y \leq 0,8\sigma_u$	
CHS chord	Compression	class 1 or 2 <sup>b</sup> and $d_0/t_0 \leq 50$ (for X-joints: $d_0/t_0 \leq 40$ )		
	Tension	$d_0/t_0 \leq 50$ (for X-joints: $d_0/t_0 \leq 40$ )		
CHS braces	Compression	class 1 or 2 and $d_i/t_i \leq 50$		
	Tension	$d_i/t_i \leq 50$		
<sup>a</sup> For X-joints with $\cos \theta_1 > \beta$ , the chord should also be checked for shear failure. <sup>b</sup> Examples of cross-section classification can be found in Eurocode 3 (see EN 1993-1-1:2005, [4] 5.5).				

## 14.2 Design moment resistance

The design moment resistance of uniplanar CHS to CHS joints shall be determined using [Table 3](#).

Table 3 — Design moment resistance of uniplanar CHS braces to CHS chord joints

Limit state	Joints with CHS braces and chord	
Chord plastification	$M_1^* = Q_u Q_f \frac{\sigma_{y0} t_0^2}{\sin \theta_1} d_1$	
Chord punching shear (for $d_1 \leq d_0 - 2t_0$ )	$M_1^* = 0,58 \sigma_{y0} d_1^2 t_0 \frac{k_b}{\sin \theta_1}$	
	Brace in-plane bending $k_b = \frac{1 + 3 \sin \theta_1}{4 \sin \theta_1}$	Brace out-of-plane bending $k_b = \frac{3 + \sin \theta_1}{4 \sin \theta_1}$
Function $Q_u$		
	Brace in-plane bending See <a href="#">Figure 1 f</a> )	Brace out-of-plane bending See <a href="#">Figure 1 g</a> )
T-, Y-, X- and gap K-joints	$Q_u = 4,3 \beta \gamma^{0,5}$	$Q_u = 1,3 \left( \frac{1 + \beta}{1 - 0,7 \beta} \right) \gamma^{0,15}$
Function $Q_f$	Same as in <a href="#">Table 2</a>	
Range of validity	Same as in <a href="#">Table 2</a>	

**15 Design resistance of uniplanar gusset plates, I- or H-section braces or RHS braces to CHS chord joints**

The design resistance of uniplanar gusset plate to CHS joints shall be determined using [Table 4](#).

Table 4 — Design resistance of uniplanar gusset plates, I- or H-section braces or RHS braces to CHS chord joints

Limit state	Brace axial load	Brace bending moment	
Chord plastification	$F_1^* = Q_u Q_f \frac{\sigma_{y0} t_0^2}{\sin \theta_1}$	$M_1^* = Q_{ub} Q_f \frac{\sigma_{y0} t_0^2}{\sin \theta_1} h_1$	
Chord punching shear (for $b_1 \leq d_0 - 2t_0$ )	I-section with $\eta \leq 2$ (axial loading and out-of-plane bending) and RHS	$\frac{F_1}{A_1} + \frac{M_{ip,1}}{W_{el,ip,1}} + \frac{M_{op,1}}{W_{el,op,1}} \leq 0,58 \sigma_{y0} \frac{t_0}{t_1}$	
	All other cases	$\frac{F_1}{A_1} + \frac{M_{ip,1}}{W_{el,ip,1}} + \frac{M_{op,1}}{W_{el,op,1}} \leq 1,16 \sigma_{y0} \frac{t_0}{t_1}$	
	Function $Q_u$		Function $Q_{ub}$ in terms of $Q_u$
CHS chord with	Brace axial load	Brace in-plane bending	Brace out-of-plane bending
Transverse plate <sup>ab</sup> See <a href="#">Figure 2 a</a> )	$Q_u = 2,2 \left( 1 + 6,8 \beta^2 \right) \gamma^{0,2}$	$Q_{ub} = 0$	$Q_{ub} = 0,5 Q_u \frac{b_1}{h_1}$
See <a href="#">Figure 2 b</a> )			$Q_{ub} = 0,5 Q_u \frac{b_1}{h_1}$
	$Q_u = 2,2 \left( \frac{1 + \beta}{1 - 0,7 \beta} \right) \gamma^{0,15}$	$Q_{ub} = 0$	$Q_{ub} = 0,5 Q_u \frac{b_1}{h_1}$

Table 4 (continued)

Longitudinal plate <sup>b</sup> See Figure 2 c) See Figure 2 d)	T	$Q_u = 5(1 + 0,4\eta)$	$Q_{ub} = 0,8Q_u$	$Q_{ub} = 0$
	X			
I-section or RHS <sup>a</sup> See Figure 3 a) or Figure 3 c)	T	$Q_u = 2,2(1 + 6,8\beta^2)(1 + 0,4\eta)\gamma^{0,2}$	$Q_{ub} = \frac{Q_u}{(1 + 0,4\eta)}$	$Q_{ub} = 0,5Q_u \frac{b_1}{h_1}$
	X	$Q_u = 2,2\left(\frac{1 + \beta}{1 - 0,7\beta}\right)(1 + 0,4\eta)\gamma^{0,15}$	$Q_{ub} = \frac{Q_u}{(1 + 0,4\eta)}$	$Q_{ub} = 0,5Q_u \frac{b_1}{h_1}$
<b>Function <math>Q_f</math></b>				
		$Q_f = (1 -  n )^{C_1}$	$n = \frac{F_0}{F_{pl,0}} + \frac{M_0}{M_{pl,0}}$ in connecting face	
<b>Brace axial load/Brace in-plane bending and out-of-plane bending</b>				
<b>Chord compression stress (<math>n &lt; 0</math>)</b>			<b>Chord tension stress (<math>n \geq 0</math>)</b>	
All joints		$C_1 = 0,25$	$C_1 = 0,20$	
<b>Range of validity</b>				
<b>General</b>		Same as in Table 2 with additional limits given below		
<b>RHS braces</b>	<b>Compression</b>	class 1 or 2 and $b_1/t_1 \leq 40$ and $h_1/t_1 \leq 40$		
	<b>Tension</b>	$b_1/t_1 \leq 40$ and $h_1/t_1 \leq 40$		
<b>I-section braces</b>	<b>Compression</b>	class 1 or 2		
	<b>Tension</b>	none		
<b>Transverse plate</b>		$b_1/d_0 \geq 0,4$		
<b>Longitudinal plate</b>		$1 \leq h_1/d_0 \leq 4$		
<p>a The chord should also be checked for shear failure for: X-joints with transverse plates and angles <math>\theta_1 &lt; 90^\circ</math>; X-joints with RHS or I-section brace members and <math>\cos \theta_1 &gt; h_1/d_0</math>.</p> <p>b For transverse and longitudinal plates, <math>\theta_1</math> is the angle of the force acting on the plate.</p>				

## 16 Design resistance of multiplanar joints with CHS chord

The design resistance for each relevant plane of a multiplanar joint shall be determined by applying the appropriate multiplanar factor  $\mu$  given in Table 5 to the resistance of the corresponding uniplanar joint calculated according to Table 2, taking account of the actual chord force in the multiplanar joint.

**Table 5 — Multiplanar factors for multiplanar CHS joints**

Type of joint	Multiplanar factor $\mu$
<b>TT-joints</b> See <a href="#">Figure 1 j</a> ) Member 1 may be either in tension or compression	$\mu = 1,0$
<b>XX-joints</b> See <a href="#">Figure 1 l</a> ) Members 1 and 2 can be either in compression or tension	$\mu = 1 + 0,35 \frac{F_2}{F_1}$ NOTE Take account of the sign of $F_1$ and $F_2$ with $ F_1  \geq  F_2 $ ; $F_2/F_1$ is negative if the members in one plane are in tension and in the other plane in compression
<b>KK-joints</b> See <a href="#">Figure 1 n</a> ) Members 1 are always in compression and members 2 are always in tension	$\mu = 1,0$ Further, in a gap joint, the cross-section in the gap has to be checked for shear failure $\left( \frac{F_{gap,0}}{F_{pl,0}} \right)^2 + \left( \frac{F_{s,gap,0}}{F_{s,pl,0}} \right)^2 \leq 1,0$ with $F_{pl,0} = A_0 \sigma_{y0}$ and $F_{s,pl,0} = 0,58 \sigma_{y0} \frac{2A_0}{\pi}$

**17 Design resistance of uniplanar RHS braces or CHS braces to RHS chord joints**

**17.1 Design axial resistance**

The design axial resistance of uniplanar RHS or CHS braces to RHS chord joints shall be determined using [Table 6](#).

**Table 6 — Design resistance of uniplanar RHS braces or CHS braces to RHS chord joints**

Limit state	Axially loaded uniplanar joints with RHS chord
<b>Chord plastification</b> (general check for gap K-joints; for T-, Y- and X-joints, if $\beta \leq 0,85$ )	$F_i^* = Q_u Q_f \frac{\sigma_{y0} t_0^2}{\sin \theta_i}$
<b>Local yielding of brace</b>	$F_i^* = \sigma_{yi} t_i \ell_{b,eff.}$
<b>Chord punching shear</b> (for $b_1 \leq b_0 - 2t_0$ )	$F_i^* = \frac{0,58 \sigma_{y0} t_0}{\sin \theta_i} \ell_{p,eff.}$

Table 6 (continued)

<b>Chord shear</b> (general check for gap K-joints; for X-joints, if $\cos \theta_1 > h_1/h_0$ )	$F_i^* = \frac{0,58\sigma_{y0}A_s}{\sin\theta_i}$	
	$F_{\text{gap},0}^* = (A_0 - A_s)\sigma_{y0} + A_s\sigma_{y0}\sqrt{1 - \left(\frac{F_{s,\text{gap},0}}{F_{s,\text{pl},0}}\right)^2}$	
<b>Chord side wall failure</b> (only for T-, Y- and X-joints with $\beta = 1,0$ )	$F_i^* = \frac{\sigma_k t_0}{\sin\theta_i} b_w Q_f$	
<b>Function <math>Q_u</math></b>		
<b>T-, Y- and X-joints</b> See Figure 1 a), Figure 1 b), and Figure 1 c)	$Q_u = \frac{2\eta}{(1-\beta)\sin\theta_1} + \frac{4}{\sqrt{1-\beta}}$	
<b>Gap K-joints</b> See Figure 1 h)	$Q_u = 14\beta\gamma^{0,3}$	
<b>Function <math>Q_f</math></b>		
	$Q_f = (1- n )^{C_1}$	$n = \frac{F_0}{F_{\text{pl},0}} + \frac{M_0}{M_{\text{pl},0}}$ in connecting face
	<b>Chord compression stress (<math>n &lt; 0</math>)</b>	<b>Chord tension stress (<math>n \geq 0</math>)</b>
<b>T-, Y- and X-joints</b>	$C_1 = 0,6 - 0,5\beta$	$C_1 = 0,10$
<b>Gap K-joints</b>	$C_1 = 0,5 - 0,5\beta$ but $\geq 0,10$	
<b>Factors</b>		
$\ell_{\text{b,eff.}}$ and $\ell_{\text{p,eff.}}$	$\ell_{\text{b,eff.}}$	$\ell_{\text{p,eff.}}$
<b>T-, Y- and X-joints</b>	$\ell_{\text{b,eff.}} = (2h_1 + 2b_e - 4t_1)$	$\ell_{\text{p,eff.}} = \left(\frac{2h_1}{\sin\theta_1} + 2b_{e,p}\right)$
<b>Gap K-joints</b>	$\ell_{\text{b,eff.}} = (2h_i + b_i + b_e - 4t_i)$	$\ell_{\text{p,eff.}} = \left(\frac{2h_i}{\sin\theta_i} + b_i + b_{e,p}\right)$
	$b_e = \left(\frac{10}{b_0/t_0}\right) \left(\frac{\sigma_{y0}t_0}{\sigma_{yi}t_i}\right) b_i$ but $\leq b_i$	$b_{e,p} = \left(\frac{10}{b_0/t_0}\right) b_i$ but $\leq b_i$
$A_s$ and $F_{s,\text{pl},0}$	$F_{s,\text{pl},0} = 0,58\sigma_{y0}A_s$	
<b>T-, Y- and X-joints</b>	$A_s = 2h_0t_0$	
<b>Gap K-joints</b>	$A_s = 2h_0t_0 + \alpha b_0t_0$	
	<b>RHS braces</b>	<b>CHS braces</b>
	$\alpha = \sqrt{\frac{1}{1 + (4g^2)/(3t_0^2)}}$	$\alpha = 0$
$b_w$	$\beta = 1,0$	$0,85 < \beta < 1,0$

**Table 6** (continued)

<b>T-, Y- and X-joints</b>	$b_w = \left( \frac{2h_1}{\sin \theta_1} + 10t_0 \right)$	Use linear interpolation between the resistance for chord plastification at $\beta = 0,85$ and the resistance for chord side wall failure at $\beta = 1,0$	
<b>Gap K-joints</b>	N/A		
$\sigma_k$	<b>Brace tension</b>	<b>Brace compression</b>	
	$\sigma_k = \sigma_{y0}$	<b>T- and Y-joints</b>	<b>X-joints</b>
		$\sigma_k = \chi \sigma_{y0}$	$\sigma_k = 0,8 \chi \sigma_{y0} \sin \theta_1$
		where $\chi$ is the reduction factor for column buckling according to e.g. Eurocode 3, using the relevant buckling curve and a slenderness $\lambda = 3,46 \left( \frac{h_0}{t_0} - 2 \right) \sqrt{\frac{1}{\sin \theta_1}}$	
<b>T-, Y-, X-, and gap K-joints with CHS brace</b>	For CHS braces, multiply the above resistances by $\pi/4$ (except for the chord shear criterion) and replace $b_i$ and $h_i$ by $d_i$ ( $i = 1, 2$ )		
<b>Range of validity</b>			
		<b>T-, Y- or X-joints</b>	<b>Gap K-joints</b>
<b>Brace-to-chord ratio</b>	<b>RHS braces</b>	$b_i/b_0 \geq 0,1 + 0,01b_0/t_0$ but $\geq 0,25$	
	<b>CHS braces</b>	$d_i/b_0 \geq 0,1 + 0,01b_0/t_0$ and $0,25 \leq d_i/b_0 \leq 0,80$	
<b>RHS chord</b>	<b>Compression</b>	class 1 or 2 and $b_0/t_0 \leq 40$ and $h_0/t_0 \leq 40$	
	<b>Tension</b>	$b_0/t_0 \leq 40$ and $h_0/t_0 \leq 40$	
<b>RHS braces</b>	<b>Compression</b>	class 1 or 2 and $b_i/t_i \leq 40$ and $h_i/t_i \leq 40$	
	<b>Tension</b>	$b_i/t_i \leq 40$ and $h_i/t_i \leq 40$	
<b>CHS braces</b>	<b>Compression</b>	class 1 or 2 and $d_i/t_i \leq 50$	
	<b>Tension</b>	$d_i/t_i \leq 50$	
<b>Gap</b>	N/A	$0,5(1 - \beta) \leq g/b_0 \leq 1,5(1 - \beta)^a$ and $g \geq t_1 + t_2$	
<b>Eccentricity</b>	N/A	$e \leq 0,25h_0$	
<b>Aspect ratio</b>	$0,5 \leq h_i/b_i \leq 2,0$		
<b>Brace angle</b>	$\theta_i \geq 30^\circ$		
<b>Yield stress</b>	$\sigma_{yi} \leq \sigma_{y0}$ and $\sigma_y \leq 0,8\sigma_u$		
<sup>a</sup>	For $g/b_0 > 1,5(1 - \beta)$ , check the joint also as two separate T- or Y-joints.		

**17.2 Design moment resistance**

The design moment resistance of uniplanar RHS braces to RHS chord joints shall be determined using [Table 7](#).

**Table 7 — Design moment resistance of uniplanar RHS braces to RHS chord joints**

Limit state	T- and X-joints ( $\theta_1 = 90^\circ$ ) <sup>a</sup>			
	Brace in-plane bending		Brace out-of-plane bending <sup>b</sup>	
	See <a href="#">Figure 1 f</a> )		See <a href="#">Figure 1 g</a> )	
<b>Chord plastification</b> (for $\beta \leq 0,85$ )	$M_{ip,1}^* = Q_u Q_f \sigma_{y0} t_0^2 h_1$		$M_{op,1}^* = Q_u Q_f \sigma_{y0} t_0^2 b_1$	
<b>Local yielding of brace</b> (for $0,85 < \beta \leq 1,0$ )	$M_{ip,1}^* = \sigma_{y1} [W_{pl,1} - (1 - \frac{b_e}{b_1}) b_1 (h_1 - t_1) t_1]$		$M_{op,1}^* = \sigma_{y1} [W_{pl,1} - 0,5 t_1 (b_1 - b_e)^2]$	
<b>Chord side wall failure</b> (for $\beta = 1,0$ ) <sup>c</sup>	$M_{ip,1}^* = 0,5 \sigma_k t_0 (h_1 + 5 t_0)^2 Q_f$		$M_{op,1}^* = \sigma_k t_0 (b_0 - t_0) (h_1 + 5 t_0) Q_f$	
<b>Function <math>Q_u</math></b>	<b>Brace in-plane bending</b>		<b>Brace out-of-plane bending</b>	
	$Q_u = \left( \frac{1}{2\eta} + \frac{2}{\sqrt{1-\beta}} + \frac{\eta}{1-\beta} \right)$		$Q_u = \left[ \frac{h_1(1+\beta)}{2b_1(1-\beta)} + \sqrt{\frac{2(1+\beta)}{\beta(1-\beta)}} \right]$	
<b>Function <math>Q_f</math></b>	Same as in <a href="#">Table 6</a>			
$b_e$	$b_e = \left( \frac{10}{b_0/t_0} \right) \left( \frac{\sigma_{y0} t_0}{\sigma_{y1} t_1} \right) b_1$ but $\leq b_1$			
$\sigma_k$	<b>Brace in-plane bending</b>		<b>Brace out-of-plane bending</b>	
	<b>T- and Y-joints</b>	<b>X-joints</b>	<b>T- and Y-joints</b>	<b>X-joints</b>
	$\sigma_k = \sigma_{y0}$	$\sigma_k = 0,8\chi\sigma_{y0}$	$\sigma_k = \chi\sigma_{y0}$	$\sigma_k = 0,8\chi\sigma_{y0}$
	where $\chi$ is the reduction factor for column buckling according to e.g. Eurocode 3 (see EN 1993-1-1[4]), using the relevant buckling curve and a slenderness $\lambda = 3,46 \left( \frac{h_0}{t_0} - 2 \right)$			
<b>Range of validity</b>	Same as in <a href="#">Table 6</a> , but $\theta_1 \approx 90^\circ$ (see footnote a)			

<sup>a</sup> The equations are conservative for  $\theta_1 < 90^\circ$ .

<sup>b</sup> Chord distortion to be prevented for brace out-of-plane bending.

<sup>c</sup> For  $0,85 < \beta < 1,0$ , use linear interpolation between the resistance for chord plastification at  $\beta = 0,85$  and the resistance for chord side wall failure at  $\beta = 1,0$ .

## 18 Design resistance of uniplanar SHS or CHS braces to SHS chord joints

### 18.1 Design axial resistance

The design axial resistance of uniplanar SHS or CHS to SHS chord joints shall be determined using [Table 8](#). These equations can be viewed as special cases of those presented in [Table 6](#).

**Table 8 — Design resistance of uniplanar SHS or CHS braces to SHS chord joints**

Limit state	Axially loaded uniplanar joints with SHS chord		
Chord plastification	$F_i^* = Q_u Q_f \frac{\sigma_{y0} t_0^2}{\sin \theta_i}$		
<b>Function <math>Q_u</math></b>			
T-, Y- and X-joints See <a href="#">Figure 1 a</a> ), <a href="#">Figure 1 b</a> ), and <a href="#">Figure 1 c</a> )	$Q_u = \frac{2\eta}{(1-\beta)\sin\theta_1} + \frac{4}{\sqrt{1-\beta}}$		
Gap K-joints See <a href="#">Figure 1 h</a> )	$Q_u = 14\beta\gamma^{0,3}$		
Function $Q_f$	Same as in <a href="#">Table 6</a>		
T-, Y-, X-, and gap K-joints with CHS brace	For CHS braces, multiply the above resistances by $\pi/4$ and replace $b_i$ and $h_i$ by $d_i$ ( $i = 1, 2$ )		
<b>Range of validity</b>			
General	Same as in <a href="#">Table 6</a> with additional limits given below		
SHS braces	T-, Y- and X-joints	$b_1/b_0 \leq 0,85$	
	Gap K-joints	$0,6 \leq (b_1 + b_2)/(2b_i) \leq 1,3$	$b_0/t_0 \geq 15$
CHS braces	Gap K-joints	$0,6 \leq (d_1 + d_2)/(2d_i) \leq 1,3$	$b_0/t_0 \geq 15$

**18.2 Design moment resistance**

The design moment resistance of uniplanar SHS brace to SHS chord joints shall be determined using [Table 7](#) with  $h_i = b_i$  and  $h_0 = b_0$ .

**19 Design resistance of uniplanar gusset plate to RHS joints**

The design axial resistance of uniplanar gusset plate to RHS joints shall be determined using [Table 9](#).

**Table 9 — Design axial resistance of uniplanar gusset plate to RHS joints**

Type of joint	Limit state
T- and X-joints — transverse plate See <a href="#">Figure 2 e</a> ) and <a href="#">Figure 2 f</a> )	<b>Chord plastification</b> (for $0,4 \leq \beta \leq 0,85$ ) $F_1^* = \sigma_{y0} t_0^2 \frac{2 + 2,8\beta}{\sqrt{1 - 0,9\beta}} Q_f$
	<b>Local yielding of plate</b> (for all $\beta$ ) $F_1^* = \sigma_{y1} t_1 b_e$
	<b>Chord punching shear</b> (for $0,85b_0 \leq b_1 \leq b_0 - 2t_0$ ) $F_1^* = 0,58\sigma_{y0} t_0 (2t_1 + 2b_{e,p})$
	<b>Chord side wall failure</b> (for $\beta \approx 1,0^a$ ) $F_1^* = \sigma_{y0} t_0 (2t_1 + 10t_0) Q_f$

Table 9 (continued)

Type of joint	Limit state	
T- and X-joints — longitudinal plate See Figure 2 g) and Figure 2 h)	Chord plastification $F_1^* = 2\sigma_{y0}t_0^2 \left( \eta + 2\sqrt{1 - \frac{t_1}{b_0}} \right) Q_f$	
T-joints — longitudinal through plate See Figure 2 i)	Chord plastification $F_1^* = 4\sigma_{y0}t_0^2 \left( \eta + 2\sqrt{1 - \frac{t_1}{b_0}} \right) Q_f$	
<b>Function <math>Q_f</math></b>		
	$Q_f = (1 -  n )^{C_1}$	$n = \frac{F_0}{F_{pl,0}} + \frac{M_0}{M_{pl,0}}$ in connecting face
	<b>Chord compression stress (<math>n &lt; 0</math>)</b>	<b>Chord tension stress (<math>n \geq 0</math>)</b>
<b>Transverse plate</b>	$C_1 = 0,03\gamma$ but $\geq 0,10$	$C_1 = 0,10$
<b>Longitudinal plate</b>	$C_1 = 0,20$	
<b>Factors</b>		
$b_e$ and $b_{e,p}$	$b_e = \left( \frac{10}{b_0/t_0} \right) \left( \frac{\sigma_{y0}t_0}{\sigma_{y1}t_1} \right) b_1$ but $\leq b_1$	$b_{e,p} = \left( \frac{10}{b_0/t_0} \right) b_1$ but $\leq b_1$
<b>Range of validity</b>		
<b>RHS chord</b>	<b>Compression</b>	class 1 or 2 and $b_0/t_0 \leq 40$ and $h_0/t_0 \leq 40$
	<b>Tension</b>	$b_0/t_0 \leq 40$ and $h_0/t_0 \leq 40$
	<b>Aspect ratio</b>	$0,5 \leq h_0/b_0 \leq 2,0$
<b>Transverse plate</b>	$b_1/b_0 \geq 0,4$	
<b>Longitudinal plate</b>	$1 \leq h_1/b_0 \leq 4$	
<b>Plate angle</b>	$\theta_1 \approx 90^\circ$	
<b>Yield stress</b>	$\sigma_{y1} \leq \sigma_{y0}$ and $\sigma_y \leq 0,8\sigma_u$	
<sup>a</sup> For $0,85 < \beta < 1,0$ , use linear interpolation between the resistance for chord plastification at $\beta = 0,85$ and the resistance for chord side wall failure at $\beta = 1,0$ .		

## 20 Design resistance of multiplanar joints with RHS chord

The design resistance for each relevant plane of a multiplanar joint shall be determined by applying the appropriate multiplanar factor  $\mu$  given in Table 10 to the resistance of the corresponding uniplanar joint calculated according to Table 6, taking account of the actual chord force in the multiplanar joint.

**Table 10 — Multiplanar factors for multiplanar RHS joints**

Type of joint	Multiplanar factor $\mu$
<b>TT-joints</b> See <a href="#">Figure 1 k</a> ) Member 1 may be either in tension or compression.	$\mu = 1,0$
<b>XX-joints</b> See <a href="#">Figure 1 m</a> ) Members 1 and 2 can be either in compression or tension.	$\mu = 1 + 0,35 \frac{F_2}{F_1} \leq 1,0 \text{ for } \beta \leq 0,85$ NOTE Take account of the sign of $F_1$ and $F_2$ with $ F_1  \geq  F_2 $ ; $F_2/F_1$ is negative if the members in one plane are in tension and in the other plane in compression.
<b>KK-joints</b> See <a href="#">Figure 1 o</a> ) Members 1 are always in compression and members 2 are always in tension	$\mu = 1,0$ Further, in a gap joint, the cross-section in the gap has to be checked for shear failure. $\left( \frac{F_{\text{gap},0}}{F_{\text{pl},0}} \right)^2 + \left( \frac{0,71 F_{\text{s,gap},0}}{F_{\text{s,pl},0}} \right)^2 \leq 1,0$ with $F_{\text{pl},0} = A_0 \sigma_{y0}$ $F_{\text{s,pl},0} = 0,58 \sigma_{y0} (0,5 A_0) \text{ for an SHS chord}$
<b>Range of validity</b>	Same as in <a href="#">Table 6</a> $\phi \approx 90^\circ$

**21 Design resistance of uniplanar CHS or RHS braces to I- or H-section chord joints**

**21.1 Design axial resistance**

The design axial resistance of uniplanar CHS or RHS braces to I- or H-section chord joints shall be determined using [Table 11](#).

**Table 11 — Design axial resistance of uniplanar CHS or RHS braces to I- or H-section chord joints**

Limit state	T-, Y-, X-, and gap K-joints See <a href="#">Figure 4 a</a> ) and <a href="#">Figure 4 b</a> )
Local yielding of brace	$F_i^* = 2 \sigma_{yi} t_i b_e$
Chord web failure	$F_i^* = \frac{\sigma_{y0} t_w b_w}{\sin \theta_i}$

Table 11 (continued)

Chord shear	$F_i^* = \frac{0,58\sigma_{y0}A_s}{\sin\theta_i}$			
	$F_{\text{gap},0}^* = (A_0 - A_s)\sigma_{y0} + A_s\sigma_{y0}\sqrt{1 - \left(\frac{F_{s,\text{gap},0}}{F_{s,\text{pl},0}}\right)^2}$			
<b>Factors</b>				
	<b>RHS braces</b>	<b>CHS braces</b>		
$b_e$	$b_e = t_w + 2r + 7t_0 \frac{\sigma_{y0}}{\sigma_{yi}}$ but $b_e \leq b_i + h_i - 2t_i$	$b_e = t_w + 2r + 7t_0 \frac{\sigma_{y0}}{\sigma_{yi}}$ but $b_e \leq 0,5\pi(d_i - t_i)$		
$b_w$	$b_w = \frac{h_i}{\sin\theta_i} + 5(t_0 + r)$ but $b_w \leq \frac{2t_i}{\sin\theta_i} + 10(t_0 + r)$	$b_w = \frac{d_i}{\sin\theta_i} + 5(t_0 + r)$ but $b_w \leq \frac{2t_i}{\sin\theta_i} + 10(t_0 + r)$		
$A_s$	$A_s = A_0 - (2 + \alpha)b_0t_0 + (t_w + 2r)t_0$			
	$\alpha = \sqrt{\frac{1}{1 + (4g^2)/(3t_0^2)}}$	$\alpha = 0$		
$F_{s,\text{pl},0}$	$F_{s,\text{pl},0} = 0,58\sigma_{y0}A_s$			
<b>Range of validity</b>				
		<b>X joints</b>	<b>T- and Y-joints</b>	<b>Gap K-joints</b>
I- or H-section chord	Compression	Flange	class 1 or 2	
		Web	class 1 and $d_w \leq 400$ mm	class 1 or 2 and $d_w \leq 400$ mm
	Tension	none		
CHS braces	Compression	class 1		
	Tension	$d_i/t_i \leq 50$		
RHS braces	Compression	class 1		
	Tension	$b_i/t_i \leq 40$ and $h_i/t_i \leq 40$		
	Aspect ratio	$0,5 \leq h_i/b_i \leq 2,0$		
Gap		N/A		$g \geq t_1 + t_2$
Eccentricity		N/A		$e \leq 0,25h_0$
Brace angle		$\theta_i \geq 30^\circ$		
Yield stress		$\sigma_{yi} \leq \sigma_{y0}$ and $\sigma_y \leq 0,8\sigma_u$		

21.2 Design moment resistance

The design moment resistance of uniplanar RHS braces (beams) to I- or H-section chord joints shall be determined using [Table 12](#).

**Table 12 — Design moment resistance of uniplanar RHS braces (beams) to I- or H-section chord joints**

Limit state	T-joints See <a href="#">Figure 4 d</a> )
Local yielding of brace	$M_{ip,1}^* = \sigma_{y1} t_1 b_e h_z$ where $h_z$ is the distance between the centres of gravity of the effective parts of the RHS brace (beam)
Chord web failure	$M_{ip,1}^* = 0,5\sigma_{y0}t_w b_w(h_1 - t_1)$
<b>Factors</b>	
$b_e$	$b_w$
$b_e = t_w + 2r + 7t_0 \frac{\sigma_{y0}}{\sigma_{y1}}$ but $\leq b_1 + h_1 - 2t_1$	$b_w = h_1 + 5(t_0 + r)$ but $\leq 2t_1 + 10(t_0 + r)$
Range of validity	Same as in <a href="#">Table 11</a> , but $\theta_1 \approx 90^\circ$

22 Design resistance of uniplanar overlap joints with a CHS, RHS, I- or H-section chord

The design axial resistance of uniplanar overlap joints with a CHS, RHS, I- or H-section chord shall be determined using [Table 13](#) and [Table 14](#). Effective width factors ( $b_{ei}$ ,  $b_{ej}$ ,  $b_{e,ov}$  and  $d_{ei}$ ,  $d_{ej}$ ,  $d_{e,ov}$ ) used in [Tables 13](#) and [14](#) are given in [Table 15](#).

**Table 13 — Design axial resistance of uniplanar overlap joints with a CHS, RHS, I- or H-section chord**

Limit state	Axially loaded overlap joints	
Local yielding of overlapping brace	$F_i^* = \sigma_{yi} t_i \ell_{b,eff.}$	
Local chord member yielding	$\left(\frac{F_0}{F_{pl,0}}\right)^c + \frac{M_0}{M_{pl,0}} \leq 1,0$	$c = 1,7$ for CHS chord $c = 1,0$ for RHS or I-section chord
Brace shear <sup>a</sup> (for $O_{v,limit} < O_v \leq 100\%$ )	$F_i \cos\theta_i + F_j \cos\theta_j \leq F_s^*$ (see <a href="#">Table 14</a> )	
	$\ell_{b,eff.}$	
	<b>CHS braces</b>	<b>RHS braces</b>
	See <a href="#">Figure 4 c</a> )	
$25\% \leq O_v < 50\%$	$\ell_{b,eff.} = \frac{\pi}{4}(2d_i + d_{ei} + d_{e,ov} - 4t_i)$	$\ell_{b,eff.} = \left(\frac{O_v}{50}\right)2h_i + b_{ei} + b_{e,ov} - 4t_i$
$50\% \leq O_v < 100\%$		$\ell_{b,eff.} = 2h_i + b_{ei} + b_{e,ov} - 4t_i$