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English Version

Eurocode 3: Design of steel structures - Part 1-10: Material toughness and through-thickness properties

Eurocode 3 - Calcul des structures en acier - Partie 1-10 : Ténacité du matériau et propriétés dans le sens de l'épaisseur

Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1-10: Stahlsortenauswahl im Hinblick auf Bruchzähigkeit und Eigenschaften in Dickenrichtung

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 250.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. prEN 1993-1-10:2023 E

Contents

Page

European foreword

This document (prEN 1993-1-10:2022) has been prepared by Technical Committee CEN/TC 250 “Structural Codes”, 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 document is currently submitted to the CEN Enquiry.

This document will supersede EN 1993-1-10:2005 and EN 1993-1-10:2005/AC:2009.

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.

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

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

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: Steel 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: Design of 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 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 steels*;

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: *Strength and stability of planar plated structures transversely loaded*;

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

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

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

EN 1993-1-11, *Design of Steel Structures* — Part 1-11: *Design of structures with tension components made of steel*;

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 such as structural fire design, cold-formed members and sheeting, stainless steels, plated structural elements, etc.

All parts numbered EN 1993-2 to EN 1993-7 treat topics relevant for a specific structural type such as 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 1993-1-10

EN 1993-1-10 gives general design rules for the selection of steel qualities to avoid brittle fracture by specifying toughness properties and to avoid lamellar tearing by specifying through-thickness properties.

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 1993-1-10

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

The national standard implementing EN 1993-1-10 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 standard is to be used.

When no national choice is made and no default is given in this standard, 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 1993-1-10 through notes to the following:

4.2.1 (4)	4.2.2.3 (1)	4.2.3 (5)	4.3 (3)
4.4 (3)	5.1 (2)	A1 (1)	

National choice is allowed in EN 1993-1-10 on the application of the following informative annexes:

Annex A

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 1993-1-10

(1) EN 1993-1-10 provides rules for the selection of steel grades and qualities related to fracture toughness to avoid brittle fracture.

NOTE Steel toughness quality is also known as subgrade.

(2) EN 1993-1-10 provides rules to specify through thickness properties for welded elements to reduce the risk of lamellar tearing.

(3) EN 1993-1-10 contains additional toughness requirements for specific cases to ensure upper shelf toughness in relation to design ultimate resistance in tension and seismic design.

(4) This document provides rules for structural steels as listed in FprEN 1993-1-1:2022. This document applies to steel grades S235 to S700.

(5) This document provides rules that apply to the selection of parent material only.

(6) This document provides rules that apply to steel materials covered by FprEN 1993-1-1:2022, 5.1 (3), provided that each individual piece of steel is tested in accordance with the requirements of FprEN 1993-1-1:2022, 5.1 (3), and EN 1090-2:2018, 5.1.

(7) This document does not apply to material salvaged from existing steelwork subjected to fatigue or fire.

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 1993-1-10 are applicable if:

— the execution quality is as specified in EN 1090-2 or EN 1090-4, 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.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. through 'should' clauses) and permissions (i.e. through 'may' clauses).

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

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

EN 1990, *Eurocode - Basis of structural design*

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

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

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

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
***KV*-value**
Charpy V-notch value
impact energy in Joules [J] required to fracture a Charpy V-notch specimen at a given test temperature T (i.e. T_{KV})

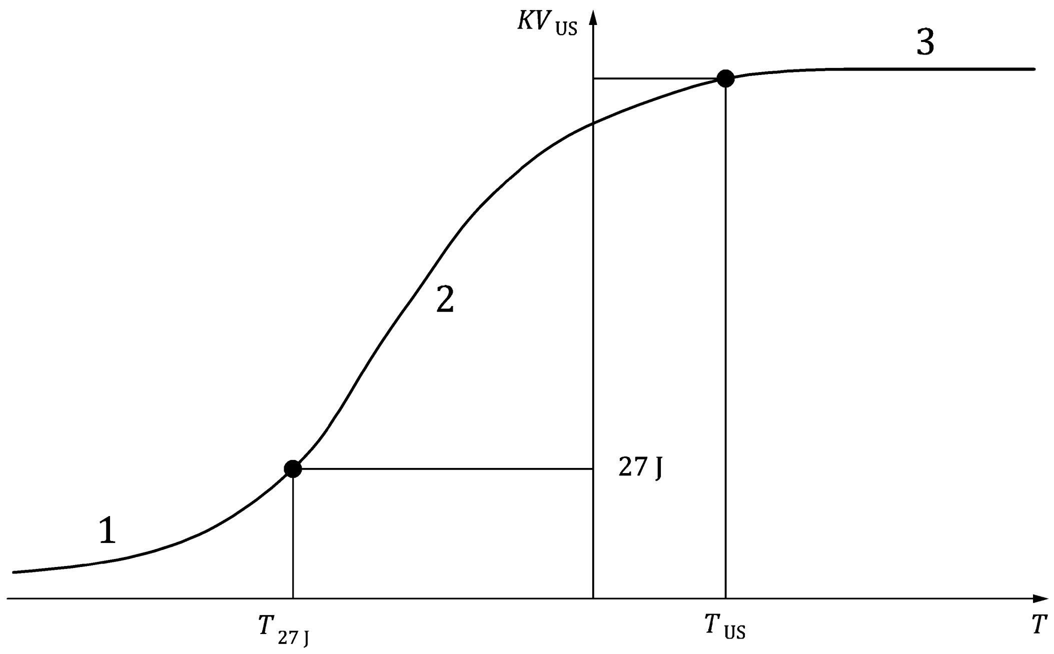
3.1.2
transition region
region of the toughness-temperature diagram showing the relationship $KV(T)$ in which the material toughness decreases with the decrease in temperature and the failure mode changes from ductile to brittle

Note 1 to entry See region 2 on Figure 3.1.

3.1.3
lower shelf region
region of the impact energy-temperature diagram in which the Charpy V-notch test specimen exhibits cleavage (brittle) modes of failure, See region 1 on Figure 3.1

3.1.4
upper shelf region
region of the toughness-temperature diagram in which the Charpy V-notch test specimen exhibits ductile modes of failure

Note 1 to entry: See region 3 on Figure 3.1



Key

1 lower shelf region

2 transition region

3 upper shelf region

NOTE Charpy transition temperature can also be T_{30J} or T_{40J} – corresponding to Charpy energy values of 30J or 40J. For an explanation of T_{27J} and T_{US} see the list of symbols.

Figure 3.1 — Example of relationship between temperature and Charpy V-notch impact energy

3.1.5
charpy transition temperature
minimum temperature in the transition region, at which the material behaviour changes from ductile to brittle

3.1.6
***Z*-value**
transverse reduction of area of a specimen in a tensile test in through-thickness direction (see EN ISO 6892-1 and EN 10164) to indicate the through-thickness ductility of a specimen, measured as a percentage

3.1.7
degree of cold forming
permanent strain from cold forming measured as a percentage

3.1.8
reference temperature
value of the lowest service steel temperature modified by temperature shifts to account for the crack geometry, the construction detail, the reliability, the strain rates and cold forming as required

3.2 Symbols and abbreviations

3.2.1 Latin upper-case symbols

CTOD	crack tip opening displacement
J	elastic plastic fracture toughness value (J-integral value) in N/mm determined as a line or surface integral that encloses the crack front from one crack surface to the other
K	stress intensity factor in $N/mm^{3/2}$
K_{Ic}	plane strain fracture toughness for linear elastic behaviour measured in $N/mm^{3/2}$
$KV(T)$	impact energy in Joule [J] in a test at temperature T_{KV} with Charpy V notch specimen
KV_{US}	impact energy in Joule [J] in a test at temperature T_{US} with Charpy V notch specimen
T	temperature [°C]
T_{Ed}	reference temperature (see 4.2.1)
T_{27J}	transition temperature at which an energy KV should not be less than 27J according to the relevant product standard in a Charpy V-notch impact test
T_{30J}	transition temperature at which an energy KV should not be less than 30J according to the relevant product standard in a Charpy V-notch impact test
T_{40J}	transition temperature at which an energy KV should not be less than 40J according to the relevant product standard in a Charpy V-notch impact test
T_{KV}	impact test temperature for a minimum specified impact energy KV in Joule [J] in a Charpy V-notch test [°C]
$T_{N,min}$	minimum steel temperature [°C] of a member in service with a return period of 50 years for air temperature recommended depending on the type of structure and including a radiation loss
T_{US}	lowest temperature [°C] at which the shear fracture appearance is 100 % in a Charpy V-notch impact test, taken as the starting point of upper shelf region (see 4.3)
Z	Z-quality class [%] differentiated by increasing levels of Z-value (see 5.2)
Z_{Ed}	required design Z-value resulting from the magnitude of strains from restrained metal shrinkage under the weld beads
Z_{Rd}	available design Z-value depending on through thickness properties of the material

3.2.2 Latin lower-case symbols

f_y	yield strength
$f_{y,nom}$	nominal yield strength
t	thickness
t_{max}	maximum permissible element thickness

3.2.3 Greek upper-case symbols

ΔT_R	safety allowance [K], if required, to reflect different reliability levels for different applications
$\Delta T_{\dot{\varepsilon}}$	temperature shift [K] considering a strain rate other than the reference strain rate $\dot{\varepsilon}_0$

$\Delta T_{\varepsilon_{cf}}$ temperature shift [K] considering the degree of cold forming ε_{cf} or ε_{eff}

ΔT_{σ} temperature shift [K] considering stress and yield strength of material, crack imperfection and member shape and dimensions, see 4.2.3 (3)

3.2.4 Greek lower-case symbols

ε_{cf} degree of cold forming (*DCF*) in percent

$\dot{\varepsilon}$ strain rate [1/s]

$\dot{\varepsilon}_0$ reference strain rate [1/s]

ε_{eff} effective strain is the average value of plastic strain in the net section

ε_{pnom} plastic strain to be used for cold bends in hollow sections

σ_{Ed} stresses accompanying the reference temperature T_{Ed}

4 Selection of materials to avoid brittle fracture

4.1 General rules

(1) To avoid brittle fracture, the selection of materials 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) The execution shall be in accordance with the requirements in EN 1090-2 or EN 1090-4.

(3) The rules in Clause 4 are applicable to elements and details subject to tensile stresses obtained using combination in Formula (4).1).

(4) The rules in Clause 4 may be applied for elements not subject to tension stresses because the rules are conservative in this situation. For elements under compression stress a minimum toughness property may be determined for a nominal stress of $\sigma_{Ed} = 0{,}25\, f_y(t)$.

(5) Steel product standards specify that test specimens shall not fail at an impact energy lower than a specified energy *KV* at a specific test temperature T_{KV}.

(6) The rules should be applied to the minimum impact energy KV_2 for the specified grade listed in the relevant steel product standard. New material of a less onerous quality (sub-grades) should not be used even though test results show equivalent or better values of impact energy.

(7) The rules contained in 4.1 refer to lower shelf toughness and the transition region, see 4.2. Additional rules for upper shelf toughness in relation to design ultimate resistance in tension and seismic design are given in 4.3 and 4.4 respectively.

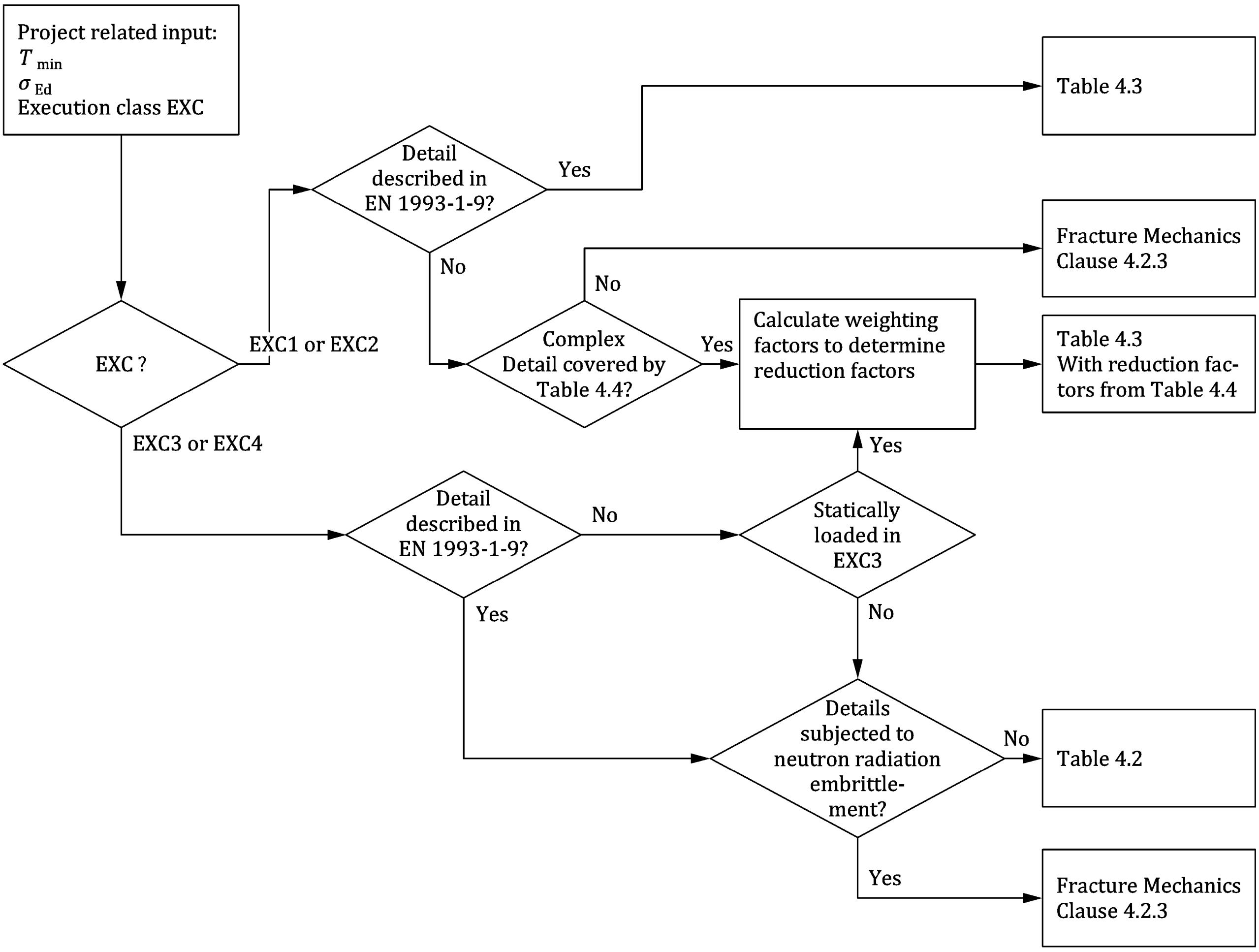
(8) The selection of a design procedure for brittle fracture assessment shall be made as shown in Figure 4.1.

NOTE The selection is based on temperature (see Formula (4).2)), stress (see Formula (4).1)) and execution classes as defined in FprEN 1993-1-1:2022, Annex A.

(9) For fatigue loaded elements in EXC 2, a reduction factor of 0,5 according to Table 4.5 should be applied to the thickness values of Table 4.3.

(10) For welded elements in EXC 3 not covered by detailed tables related to nominal stress methods in EN 1993-1-9, and which are statically loaded, 4.2.2.3 should be applied.

(11) For details subjected to neutron radiation embrittlement, e.g. structures of nuclear power plants, their toughness should be determined using fracture mechanics according to 4.2.3.



NOTE Table 4.2 for EXC3 and EXC4 was developed mainly for fatigue loaded elements and Table 4.3 for EXC1 and EXC2 was developed mainly for static loaded elements.

Figure 4.1 — Flowchart of material selection procedures for brittle fracture assessment

4.2 Toughness requirements for the lower shelf and the transition region

4.2.1 Procedure

(1) The steel quality should be selected taking account of the following:

(i) steel material properties:

- yield strength depending on the material thickness f_y(t)
- toughness quality expressed in terms of T_{27J}, T_{30J} or T_{40J}

(ii) member characteristics:

- member shape and detail
- stress concentrations according to the details geometry and loaded element thickness (t)
- appropriate assumptions for fabrication flaws (e.g. as through-depth cracks or as semi-elliptical surface cracks)

(iii) design situations:

- design value of minimum steel temperature
- maximum applied stresses from permanent and variable actions derived from the design condition described in (4) below
- residual stress
- assumptions for crack growth from fatigue loading during an inspection interval (if relevant)
- strain rate $\dot{\varepsilon}$ from accidental actions (if relevant)
- degree of cold forming (ε_{cf} and ε_{eff}) (if relevant)

(iv) Execution Class according to FprEN 1993-1-1:2022, Annex A.

(2) The maximum permissible thickness of steel elements for fracture should be obtained from Table 4.2 and Table 4.3.

(3) The following design condition should be used:

(i) The maximum nominal applied stress σ_{Ed} should be obtained according to the combination of actions in Formula (4).1):

$$E_d = E\{ A[T_{Ed}] \text{“+”} \sum G_K \text{“+”} \psi_1 Q_{K1} \text{“+”} \sum \psi_{2,i} Q_{Ki} \} \quad (4.1)$$

where:

A is the leading action represented by the reference temperature T_{Ed} that influences the toughness of material of the member considered and might also lead to stress from restraint of movement,

$\sum G_K$ are the permanent actions,

$\psi_1 Q_{K1}$ is the frequent value of the variable load and

$\psi_{2i} Q_{Ki}$ are the quasi-permanent values of the accompanying variable loads, that govern the level of stresses on the material.

(ii) The combination factors ψ_1 and ψ_2 should be in accordance with EN 1990.

(iii) The maximum applied stress σ_{Ed} should be the maximum nominal design tensile stress at the location of the potential fracture initiation. The applied stress σ_{Ed} shall be determined by elastic analyses. Second order effects should be considered where relevant.

NOTE 1 The combination in Formula (4).1) is considered to be equivalent to an accidental combination, because of the assumption of simultaneous occurrence of lowest temperature, flaw size, location of flaw and material property.

NOTE 2 σ_{Ed} can include stresses from restraint of movement from temperature change.

NOTE 3 As the leading action is the reference temperature T_{Ed}, the maximum applied stress σ_{Ed} generally will not exceed 75 % of the yield strength.

(4) The reference temperature T_{Ed} at the potential fracture location should be determined using Formula (4).2):

$$T_{Ed} = T_{N,min} + \Delta T_{\sigma} + \Delta T_{R} + \Delta T_{\dot{\varepsilon}} + \Delta T_{\varepsilon_{cf}} \quad (4.2)$$

where

$T_{N,min}$ is the minimum uniform steel temperature with a specified return period for external components; see EN 1991-1-5. For the extreme value of the minimum air temperature a return period of 50 years should be applied depending on the type of structure.

The method employed to calculate the temperature shift $\Delta T_{\varepsilon_{cf}}$ due to cold forming is based on non-fine grain steels and is conservative for fine grain steels. If available, other appropriate rules may be used to consider cold forming effects.

NOTE 1 A maximum value for the difference of 40 K is ($T_{KV} \leq T_{N,min} + 40$ K). The National annex can give the maximum value by which the minimum steel temperature of the steel $T_{N,min}$ can be below the impact test temperature T_{KV}.

ΔT_{σ} is the adjustment for stress and yield strength of material, crack imperfection and member shape and dimensions,

NOTE 2 ΔT_{σ} is equal to 0 K for the calculation of T_{Ed} according to Formula (4).2), when determining the maximum permitted thickness values according to 4.2.2.2. This is because in preparing the tabulated values in 4.2.2 a standard curve has been used for the temperature shift ΔT_{σ} that envelopes the design values of the stress intensity factor function K from applied stresses σ_{Ed} and residual stresses and includes the Wallin-Sanz-correlation between the stress intensity factor function [K] and the temperature T.

NOTE 3 The National annex can limit the range of σ_{Ed}, to which the validity of values for permissible thicknesses in Table 4.2 and Table 4.3 can be restricted.

ΔT_{R} is a safety allowance, if required, to reflect different reliability levels for different applications

NOTE 4 When using the tabulated values according to 4.2.2 the safety element ΔT_{R} is equal to 0 K unless the National annex gives a different value to adjust T_{Ed} to other reliability requirements. When using material values obtained from testing, the safety element ΔT_{R} is equal to −38 K unless the National annex gives a different value.

$\Delta T_{\dot{\varepsilon}}$ is the adjustment for a strain rate other than the reference strain rate $\dot{\varepsilon}_0$, see Formula (4).5)

$\Delta T_{\varepsilon_{cf}}$ is the adjustment for the degree of cold forming ε_{cf}, see Formula (4).6)

NOTE 5 Alternative methods can be used to determine the toughness requirements. Further information is given in 4.2.3.

4.2.2 Maximum permitted thickness values

4.2.2.1 General

(1) For Execution Class 3 and 4 the maximum permissible thickness may be selected from Table 4.2. For Execution Class 1 and 2 the maximum permissible thickness may be selected from Table 4.3 or Table 4.2 if appropriate. The Execution Class may be determined according to FprEN 1993-1-1:2022, Table A1.

NOTE 1 The procedure as illustrated in the flow chart shown in Figure 4.1 applies.

NOTE 2 Table 4.2 and Table 4.3 give the maximum permissible element thickness t_{max} appropriate to a steel grade, its toughness quality in terms of KV-value, the applied stress level [σ_{Ed}] and the reference temperature [T_{Ed}].

NOTE 3 The values in Tables 4.2 and 4.3 are based on the following assumptions:

- The values satisfy the reliability requirements of EN 1990;
- A strain rate $\dot{\varepsilon}$ = 4×10⁻⁴/s has been used which covers the dynamic action effects for most transient and persistent design situations;
- Non-cold-formed material with ε_{cf} = 0 %;
- The nominal notch toughness values in terms of T_{27J} are based on the following product standards: EN 10025 (all parts), EN 10210-1, EN 10210-2, EN 10219-1, EN 10219-2 and EN 10149-2. For other values the following correlations have been used

$$T_{40J} = T_{27J} + 10 \quad [°C] \tag{4.3}$$

$$T_{30J} = T_{27J} + 0 \quad [°C] \tag{4.4}$$

NOTE 4 For members subject to fatigue all detail categories for nominal stresses in EN 1993-1-9 are covered.

NOTE 5 For structures with predominate static loading, a simplified method to account for complex geometries is given in 4.2.2.3.

In determining Table 4.2, fatigue has been considered by applying a fatigue load to a detail with an assumed initial flaw. The damage assumed in these members is one quarter of the full fatigue damage obtained from nominal stress approach according to EN 1993-1-9. This assumption permits a minimum number of periods between in-service inspections when inspections should be specified for damage tolerance according to EN 1993-1-9. An inspection at the end-of-life is only required for life extension. Fatigue loaded members designed according to EN 1993-1-9 using the safe life concept as well as statically loaded members according to Table 4.3 do not require any in-service inspection in relation to brittle fracture, provided they are executed according to the requirements of EN 1090-2.

(2) For high strain rates $\dot{\varepsilon}$ > 4 × 10⁻⁴/s (e.g. for impact loads) the tabulated values in Table 4.2 and Table 4.3 may be used by reducing T_{Ed} by $\Delta T_{\dot{\varepsilon}}$ given by Formula (4).5):

$$\Delta T_{\dot{\varepsilon}} = -\frac{1440 - f_y(t)}{550} \times \left(\ln \frac{\dot{\varepsilon}}{\dot{\varepsilon}_0} \right)^{1,5} \quad [K] \tag{4.5}$$

with

$\dot{\varepsilon}_0 = 10^{-4} / s$ as the reference strain rate.

(3) To allow for cold forming of non-ageing steels, the tabulated values in Table 4.2 and Table 4.3 may be used by adjusting T_{Ed} by adding $\Delta T_{\varepsilon_{cf}}$ given by Formula (4).6):

$$\Delta T_{\varepsilon_{cf}} = -3 \times \varepsilon_{cf} \quad [K] \tag{4.6}$$

with 0 K ≥ $\Delta T_{\varepsilon_{cf}}$ ≥ −45 K

where ε_{cf} is the value of the plastic strain due to cold forming.

(4) For circular cold-formed hollow sections according to EN 10219-1 and EN 10219-2 and other cold-formed sections to EN 1993-1-3, the adjustment in Formula (4).7) may be used due to cold forming effects:

$$\Delta T_{\varepsilon_{cf}} = -3\ \varepsilon_{eff}\ [K] \text{ for } \varepsilon_{eff} > 2\ \% \qquad (4.7)$$

where ε_{eff} is the average value of plastic strain in the net section.

NOTE 1 The value of ε_{eff} depends on the wall thickness and the inner radius r_i.

NOTE 2 Table 4.1 gives the relationship between the radius of the cold bend and the maximum value of plastic strain ε_{pnom} as well the value ε_{eff} for different wall thickness t.

Table 4.1 — Definition of ε_{pnom} and ε_{eff} for radius r_i of cold bend

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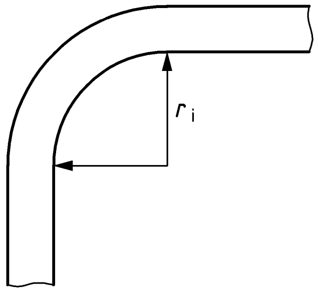
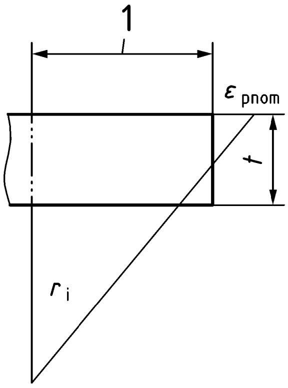
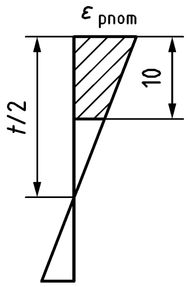
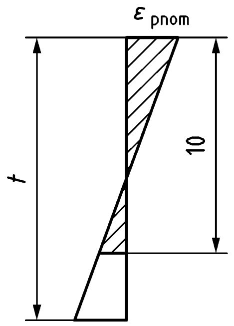
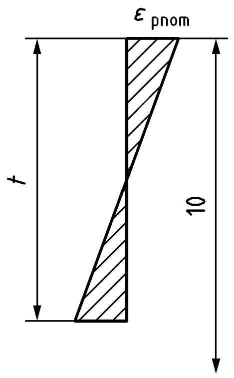
<tr><td colspan="2">


</td><td>$\varepsilon_{pnom} = \frac{t}{2r_i + t}$</td></tr>
<tr><td colspan="3">Determination of effective strain ε_{eff}</td></tr>
<tr><td>t</td><td>ε_{pnom} distribution</td><td>ε_{eff}</td></tr>
<tr><td>≥ 20</td><td>
</td><td>$\varepsilon_{pnom}\left(1 - \frac{10}{t}\right)$</td></tr>
<tr><td>< 20
≥ 10</td><td>
</td><td>$\frac{\varepsilon_{pnom}}{2}\left(\frac{t}{20} + \frac{(20-t)^2}{20t}\right)$</td></tr>
<tr><td>< 10</td><td>
</td><td>$\frac{\varepsilon_{pnom}}{2}\frac{t}{10}$</td></tr>
</table>

(5) For $r_i/t > 15$ cold forming effects due to production may be neglected. For $r_i/t \leq 15$, the maximum value for $\Delta T_{\varepsilon_{cf}}$ may be taken as $\Delta T_{\varepsilon_{cf}} = -20$ K.

NOTE For rectangular hollow sections delivered according to EN 10219, the adjustment $\Delta T_{\varepsilon_{cf}}$ reads:

$\Delta T_{\varepsilon_{cf}} = -35$ [K] for $t \leq 16$ mm

$\Delta T_{\varepsilon_{cf}}$ = −45 [K] for $t > 16$ mm

unless otherwise determined by tests.

4.2.2.2 Determination of maximum permissible values of element thickness

(1) For Execution Class 3 and 4 the maximum permissible thickness may be selected from Table 4.2. For Execution Class 1 and 2 the maximum permissible thickness may be selected from Table 4.3 or Table 4.2 if appropriate. The Execution Class may be determined according to FprEN 1993-1-1:2022, Table A1.

(2) The thicknesses are presented in terms of three stress levels expressed as proportions of the nominal yield strength:

a) $\sigma_{Ed} = 0{,}75\, f_y(t)$ [N/mm²]

b) $\sigma_{Ed} = 0{,}50\, f_y(t)$ [N/mm²]

c) $\sigma_{Ed} = 0{,}25\, f_y(t)$ [N/mm²]

(3) The value of the nominal yield strength $f_y(t)$ may be determined either from Formula (4).8) or may be taken as R_{eH}-values from the relevant product standards.

$$f_y\left(t\right) = f_{y,nom} - 0{,}25\frac{t}{t_0} \quad \left[\mathrm{N/mm^2}\right] \tag{4.8}$$

where

t is the thickness of the plate in mm

t_0 = 1 mm

NOTE The tabulated values are given in terms of a choice of seven reference temperatures: +10, 0, −10, −20, −30, −40, −50, −80 and −120°C.

(4) Any extrapolations beyond the extreme values of the stresses indicated in Table 4.2 and Table 4.3 should not be done.

Table 4.2 — Maximum permissible values of element thickness t in mm for Execution Classes EXC3 and EXC4

Steel grade	Quality	KV		Reference Temperature T_{Ed} [°C]																										
		T [°C]	J_{min}	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120
				$\sigma_{Ed} = 0,75 \cdot f_y(t)$									$\sigma_{Ed} = 0,5 \cdot f_y(t)$									$\sigma_{Ed} = 0,25 \cdot f_y(t)$								
S235	JR	20	27	60	50	40	35	30	25	20	10	5	90	75	65	55	45	40	35	20	15	135	115	100	85	75	65	60	40	30
	J0	0	27	90	75	60	50	40	35	30	15	10	125	105	90	75	65	55	45	30	15	175	155	135	115	100	85	75	50	35
	J2	−20	27	125	105	90	75	60	50	40	25	10	170	145	125	105	90	75	65	40	20	200	200	175	155	135	115	100	65	40
S275	JR	20	27	55	45	35	30	25	20	15	10	5	80	70	55	50	40	35	30	20	10	125	110	95	80	70	60	55	40	25
	J0	0	27	75	65	55	45	35	30	25	15	5	115	95	80	70	55	50	40	25	15	165	145	125	110	95	80	70	45	30
	J2	−20	27	110	95	75	65	55	45	35	20	10	155	130	115	95	80	70	55	35	20	200	190	165	145	125	110	95	60	40
	K2,M,N	−20	40	135	110	95	75	65	55	45	25	10	180	155	130	115	95	80	70	40	20	200	200	190	165	145	125	110	70	40
	ML,NL	−50	27	185	160	135	110	95	75	65	35	15	200	200	180	155	130	115	95	55	30	200	200	200	200	190	165	145	95	55
S355	JR	20	27	40	35	25	20	15	15	10	5	5	65	55	45	40	30	25	25	15	10	110	95	80	70	60	55	45	30	20
	J0	0	27	60	50	40	35	25	20	15	10	5	95	80	65	55	45	40	30	20	10	150	130	110	95	80	70	60	40	25
	J2	−20	27	90	75	60	50	40	35	25	15	5	135	110	95	80	65	55	45	25	15	200	175	150	130	110	95	80	55	30
	J4	−40	27	130	110	90	75	60	50	40	20	10	180	155	135	110	95	80	65	40	20	200	200	195	170	150	130	110	70	40
	K2,M,N	−20	40	110	90	75	60	50	40	35	20	5	155	135	110	95	80	65	55	30	15	200	200	175	150	130	110	95	60	35
	J5,ML,NL	−50	27	155	130	110	90	75	60	50	25	10	200	180	155	135	110	95	80	45	25	210	200	200	200	175	150	130	80	45
S420	JR	20	27	35	30	20	20	15	10	10	5	-	60	50	40	35	25	20	20	10	5	100	85	75	65	55	45	40	30	20
	J0	0	27	55	45	35	30	20	20	15	5	-	85	70	60	50	40	35	25	15	10	140	120	100	85	75	65	55	35	20
	J2	−20	27	80	65	55	45	35	30	20	10	5	120	100	85	70	60	50	40	20	10	185	160	140	120	100	85	75	45	30
	J4	−40	27	115	95	80	65	55	45	35	20	5	165	140	120	100	85	70	60	35	15	200	200	185	160	140	120	100	65	35

	K2,M,N	−20	40	95	80	65	55	45	35	30	15	5	140	120	100	85	70	60	50	25	15	200	185	160	140	120	100	85	55	30
	J5,ML,NL	−50	27	135	115	95	80	65	55	45	20	10	190	165	140	120	100	85	70	40	20	200	200	200	185	160	140	120	75	40
S460	JR	20	27	30	25	20	15	10	10	5	5	-	55	45	35	30	25	20	15	10	5	95	80	70	60	50	45	40	25	15
	J0	0	27	50	40	30	25	20	15	10	5	-	80	65	55	45	35	30	25	15	5	130	115	95	80	70	60	50	35	20
	J2	−20	27	75	60	50	40	30	25	20	10	5	110	95	80	65	55	45	35	20	10	175	150	130	115	95	80	70	45	25
	J4	−40	27	105	90	75	60	50	40	30	15	5	155	130	110	95	80	65	55	30	15	200	200	175	150	130	115	95	60	35
	K2,M,N	−20	40	90	75	60	50	40	30	25	10	5	130	110	95	80	65	55	45	25	10	200	175	150	130	115	95	80	50	30
	J5,ML,NL	−50	27	125	105	90	75	60	50	40	20	5	180	155	130	110	95	80	65	35	15	200	200	200	175	150	130	115	70	40
	Q	−20	30	75	60	50	40	30	25	20	10	5	110	95	80	65	55	45	35	20	10	175	150	130	115	95	80	70	45	25
	QL	−40	30	105	90	75	60	50	40	30	15	5	155	130	110	95	80	65	55	30	15	200	200	175	150	130	115	95	60	35
	QL1	−60	30	150	125	105	90	75	60	50	25	10	200	180	155	130	110	95	80	45	20	200	200	200	200	175	150	130	80	45
S500	J0	0	27	45	35	30	20	20	15	10	5	-	70	60	50	40	35	25	20	10	5	125	105	90	80	65	55	50	30	20
	K2,M,N	−20	40	80	65	55	45	35	30	20	10	5	125	105	85	70	60	50	40	20	10	195	170	145	125	105	90	80	50	25
	ML,NL	−50	27	120	100	80	65	55	45	35	20	5	170	145	125	105	85	70	60	35	15	250	220	195	170	145	125	105	65	35
	Q	0	40	55	45	35	30	20	20	15	5	-	85	70	60	50	40	35	25	15	5	145	125	105	90	80	65	55	35	20
	Q	−20	30	65	55	45	35	30	20	20	10	5	105	85	70	60	50	40	35	20	10	170	145	125	105	90	80	65	40	25
	QL	−20	40	80	65	55	45	35	30	20	10	5	125	105	85	70	60	50	40	20	10	195	170	145	125	105	90	80	50	25
	QL	−40	30	100	80	65	55	45	35	30	15	5	145	125	105	85	70	60	50	25	10	220	195	170	145	125	105	90	55	30
	QL1	−40	40	120	100	80	65	55	45	35	20	5	170	145	125	105	85	70	60	35	15	250	220	195	170	145	125	105	65	35
	QL1	−60	30	140	120	100	80	65	55	45	20	10	195	170	145	125	105	85	70	40	20	250	250	220	195	170	145	125	80	40

Steel grade	**Quality**	**KV**		**Reference Temperature T_{Ed} [°C]**																										
		T [°C]	**J_{min}**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**-80**	**-120**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**-80**	**-120**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**-80**	**-120**
				$\sigma_{Ed} = 0{,}75 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}5 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}25 \cdot f_y(t)$								
S550	MC	−20	40	75	60	50	40	30	25	20	10	5	115	95	80	65	55	45	35	20	10	185	160	140	120	100	85	75	45	25
	Q	0	40	50	40	30	25	20	15	10	5	-	80	65	55	45	35	30	25	15	5	140	120	100	85	75	60	55	35	20
	Q	−20	30	60	50	40	30	25	20	15	5	-	95	80	65	55	45	35	30	15	5	160	140	120	100	85	75	60	40	20
	QL	−20	40	75	60	50	40	30	25	20	10	5	115	95	80	65	55	45	35	20	10	185	160	140	120	100	85	75	45	25
	QL	−40	30	90	75	60	50	40	30	25	10	5	135	115	95	80	65	55	45	25	10	210	185	160	140	120	100	85	55	30
	QL1	−40	40	110	90	75	60	50	40	30	15	5	160	135	115	95	80	65	55	30	15	240	210	185	160	140	120	100	60	35
	QL1	−60	30	130	110	90	75	60	50	40	20	5	185	160	135	115	95	80	65	35	15	250	240	210	185	160	140	120	75	40
S600	MC	−20	40	70	55	45	35	30	20	15	5	-	105	90	75	60	50	40	35	20	5	175	155	130	110	95	80	70	40	20
S620	Q	0	40	45	35	25	20	15	15	10	5	-	70	60	50	40	30	25	20	10	5	130	110	95	80	65	55	50	30	15
	Q	−20	30	55	45	35	25	20	15	15	5	-	85	70	60	50	40	30	25	15	5	150	130	110	95	80	65	55	35	20
	QL	−20	40	65	55	45	35	25	20	15	5	-	105	85	70	60	50	40	30	15	5	175	150	130	110	95	80	65	40	20
	QL	−40	30	80	65	55	45	35	25	20	10	5	125	105	85	70	60	50	40	20	10	200	175	150	130	110	95	80	50	25
	QL1	−40	40	100	80	65	55	45	35	25	15	5	145	125	105	85	70	60	50	25	10	230	200	175	150	130	110	95	55	30
	QL1	−60	30	120	100	80	65	55	45	35	15	5	170	145	125	105	85	70	60	30	15	250	230	200	175	150	130	110	65	35

Steel grade	Quality	KV		Reference Temperature T_{Ed} [°C]																										
		T [°C]	J_{min}	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120
				$\sigma_{Ed} = 0{,}75 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}5 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}25 \cdot f_y(t)$								
S650	MC	−20	40	65	50	40	35	25	20	15	5	-	100	85	70	55	45	40	30	15	5	170	145	125	105	90	75	65	40	20
S690 a	Q	0	40	40	30	25	20	15	10	10	5	-	65	55	45	35	30	20	20	10	5	120	100	85	75	60	50	45	25	15
	Q	−20	30	50	40	30	25	20	15	10	5	-	80	65	55	45	35	30	20	10	5	140	120	100	85	75	60	50	30	15
	QL	−20	40	60	50	40	30	25	20	15	5	-	95	80	65	55	45	35	30	15	5	165	140	120	100	85	75	60	35	20
	QL	−40	30	75	60	50	40	30	25	20	10	-	115	95	80	65	55	45	35	20	5	190	165	140	120	100	85	75	45	20
	QL1	−40	40	90	75	60	50	40	30	25	10	5	135	115	95	80	65	55	45	25	10	200	190	165	140	120	100	85	50	25
	QL1	−60	30	110	90	75	60	50	40	30	15	5	160	135	115	95	80	65	55	30	10	200	200	190	165	140	120	100	60	30
S700	MC	−20	40	60	45	40	30	25	20	15	5	-	95	80	65	55	45	35	30	15	5	165	140	120	100	85	70	60	35	20

a For ordering products made of S690 steels, the test temperature T_{KV} for the selected subgrade shall be specified.

Linear interpolation may be used in applying Table 4.2. Most applications require σ_{Ed} values between σ_{Ed} = 0,75 $f_y(t)$ and σ_{Ed} = 0,50 $f_y(t)$.

Where a dash is shown in Table 4.2 the result will be less than 5 mm and the background design procedure is not valid. These steel grades and qualities should not be used under these conditions unless specialist advice is sought.

Table 4.2 has been derived for the Charpy energy values KV for specimens in the rolling direction of the product. Charpy energy values KV for specimens perpendicular to the rolling direction of the product can be lower than the values for specimens in the direction of the rolling. If required, minimum Charpy energy values perpendicular to the rolling direction may be specified in accordance with product standard options.

NOTE 1 For elements under compression stress see 4.1 (4).

NOTE 2 All the sizes shown in Table 4.2 are not necessarily included in the relevant product standards.

Table 4.3 — Maximum permissible values of element thickness *t* in mm for Execution Classes EXC1 and EXC2

Steel grade	Quality	KV		Reference Temperature T_{Ed} [°C]																										
		T [°C]	J_{min}	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120
				$\sigma_{Ed} = 0{,}75 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}5 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}25 \cdot f_y(t)$								
S235	JR	20	27	250	250	170	120	90	65	50	25	15	250	250	250	250	190	145	110	55	30	250	250	250	250	250	250	250	135	75
	J0	0	27	250	250	250	250	170	120	90	40	15	250	250	250	250	250	250	190	85	40	250	250	250	250	250	250	250	200	100
	J2	−20	27	250	250	250	250	250	250	170	65	25	250	250	250	250	250	250	250	145	55	250	250	250	250	250	250	250	250	135
S275	JR	20	27	250	185	130	95	70	50	40	20	10	250	250	250	205	150	115	90	45	25	250	250	250	250	250	250	215	120	65
	J0	0	27	250	250	250	185	130	95	70	30	15	250	250	250	250	250	205	150	70	30	250	250	250	250	250	250	250	175	85
	J2	−20	27	250	250	250	250	250	185	130	50	20	250	250	250	250	250	250	250	115	45	250	250	250	250	250	250	250	250	120
	K2,M,N	−20	40	250	250	250	250	250	250	185	70	25	250	250	250	250	250	250	250	150	55	250	250	250	250	250	250	250	250	140
	ML,NL	−50	27	250	250	250	250	250	250	250	130	40	250	250	250	250	250	250	250	250	90	250	250	250	250	250	250	250	250	215
S355	JR	20	27	165	115	85	60	45	35	25	10	5	250	250	190	140	105	80	60	30	15	250	250	250	250	250	210	165	90	50
	J0	0	27	250	240	165	115	85	60	45	20	5	250	250	250	250	190	140	105	45	20	250	250	250	250	250	250	250	135	65
	J2	−20	27	250	250	250	240	165	115	85	35	10	250	250	250	250	250	250	190	80	30	250	250	250	250	250	250	250	210	90
	J4	−40	27	250	250	250	250	250	240	165	60	20	250	250	250	250	250	250	250	140	45	250	250	250	250	250	250	250	250	135
	K2,M,N	−20	40	250	250	250	250	240	165	115	45	15	250	250	250	250	250	250	250	105	35	250	250	250	250	250	250	250	250	110
	J5,ML,NL	−50	27	250	250	250	250	250	250	240	85	25	250	250	250	250	250	250	250	190	60	250	250	250	250	250	250	250	250	165
S420	JR	20	27	120	85	60	45	30	25	20	10	5	250	200	145	105	80	60	45	25	10	250	250	250	250	225	175	140	75	40
	J0	0	27	250	175	120	85	60	45	30	15	5	250	250	250	200	145	105	80	35	15	250	250	250	250	250	250	225	110	55
	J2	−20	27	250	250	250	175	120	85	60	25	10	250	250	250	250	250	200	145	60	25	250	250	250	250	250	250	250	175	75
	J4	−40	27	250	250	250	250	250	175	120	45	15	250	250	250	250	250	250	250	105	35	250	250	250	250	250	250	250	250	110

	M,N	−20	40	250	250	250	250	175	120	85	30	10	250	250	250	250	250	250	200	80	30	250	250	250	250	250	250	250	225	90
	J5,ML, NL	−50	27	250	250	250	250	250	250	175	60	20	250	250	250	250	250	250	250	145	45	250	250	250	250	250	250	250	250	140
S460	JR	20	27	105	70	50	35	25	20	15	5	-	235	170	125	90	70	50	40	20	10	250	250	250	250	200	155	125	65	35
	J0	0	27	210	145	105	70	50	35	25	10	5	250	250	235	170	125	90	70	30	15	250	250	250	250	250	250	200	100	45
	J2	−20	27	250	250	210	145	105	70	50	20	5	250	250	250	250	235	170	125	50	20	250	250	250	250	250	250	250	155	65
	J4	−40	27	250	250	250	250	210	145	105	35	10	250	250	250	250	250	250	235	90	30	250	250	250	250	250	250	250	250	100
	K2,M, N	−20	40	250	250	250	210	145	105	70	25	10	250	250	250	250	250	240	170	70	25	250	250	250	250	250	250	250	205	80
	J5,ML, NL	−50	27	250	250	250	250	250	210	145	50	15	250	250	250	250	250	250	250	125	40	250	250	250	250	250	250	250	250	125
	Q	−20	30	250	250	210	145	105	70	50	20	5	250	250	250	250	240	170	125	50	20	250	250	250	250	250	250	250	155	65
	QL	−40	30	250	250	250	250	210	145	105	35	10	250	250	250	250	250	250	240	90	30	250	250	250	250	250	250	250	250	100
	QL1	−60	30	250	250	250	250	250	250	210	70	20	250	250	250	250	250	250	250	170	50	250	250	250	250	250	250	250	250	155
S500	J0	0	27	180	125	90	60	45	30	25	10	5	250	250	205	150	110	80	60	25	10	250	250	250	250	250	240	185	90	40
	K2,M, N	−20	40	250	250	250	180	125	90	60	25	5	250	250	250	250	250	205	150	60	20	250	250	250	250	250	250	250	185	70
	ML,NL	−50	27	250	250	250	250	250	180	125	45	10	250	250	250	250	250	250	250	110	35	250	250	250	250	250	250	250	250	110
	Q	0	40	250	180	125	90	60	45	30	10	5	250	250	250	205	150	110	80	35	15	250	250	250	250	250	250	240	110	50
	Q	−20	30	250	250	180	125	90	60	45	15	5	250	250	250	250	205	150	110	45	15	250	250	250	250	250	250	250	140	60
	QL	−20	40	250	250	250	180	125	90	60	25	5	250	250	250	250	250	205	150	60	20	250	250	250	250	250	250	250	185	70
	QL	−40	30	250	250	250	250	180	125	90	30	10	250	250	250	250	250	250	205	80	25	250	250	250	250	250	250	250	240	90
	QL1	−40	40	250	250	250	250	250	180	125	45	10	250	250	250	250	250	250	250	110	35	250	250	250	250	250	250	250	250	110
	QL1	−60	30	250	250	250	250	250	250	180	60	15	250	250	250	250	250	250	250	150	45	250	250	250	250	250	250	250	250	140

Steel grade	Quality	KV		Reference Temperature T_{Ed} [°C]																										
		T [°C]	J_{min}	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120
				$\sigma_{Ed} = 0{,}75 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}5 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}25 \cdot f_y(t)$								
S550	MC	−20	40	250	250	215	150	105	75	50	20	5	250	250	250	250	245	175	125	50	15	250	250	250	250	250	250	250	160	65
	Q	0	40	215	150	105	75	50	35	25	10	5	250	250	245	175	125	90	65	30	10	250	250	250	250	250	250	210	100	45
	Q	−20	30	250	215	150	105	75	50	35	15	5	250	250	250	245	175	125	90	35	15	250	250	250	250	250	250	250	125	50
	QL	−20	40	250	250	215	150	105	75	50	20	5	250	250	250	250	245	175	125	50	15	250	250	250	250	250	250	250	160	65
	QL	−40	30	250	250	250	215	150	105	75	25	5	250	250	250	250	250	245	175	65	20	250	250	250	250	250	250	250	210	80
	QL1	−40	40	250	250	250	250	215	150	105	35	10	250	250	250	250	250	250	245	90	30	250	250	250	250	250	250	250	250	100
	QL1	−60	30	250	250	250	250	250	215	150	50	15	250	250	250	250	250	250	250	125	35	250	250	250	250	250	250	250	250	125
S600	MC	−20	40	250	250	185	130	90	60	45	15	5	250	250	250	250	210	150	110	40	15	250	250	250	250	250	250	250	145	55
S620	Q	0	40	175	120	85	60	40	30	20	5	-	250	250	200	145	105	75	55	25	10	250	250	250	250	250	240	180	85	35
	Q	−20	30	250	175	120	85	60	40	30	10	5	250	250	250	200	145	105	75	30	10	250	250	250	250	250	250	240	105	45
	QL	−20	40	250	250	175	120	85	60	40	15	5	250	250	250	250	200	145	105	40	15	250	250	250	250	250	250	250	135	55
	QL	−40	30	250	250	250	175	120	85	60	20	5	250	250	250	250	250	200	145	55	15	250	250	250	250	250	250	250	180	65
	QL1	−40	40	250	250	250	250	175	120	85	30	5	250	250	250	250	250	250	200	75	25	250	250	250	250	250	250	250	240	85
	QL1	−60	30	250	250	250	250	250	175	120	40	10	250	250	250	250	250	250	250	105	30	250	250	250	250	250	250	250	250	105

Steel grade	Quality	KV		Reference Temperature T_{Ed} [°C]																										
		T [°C]	J_{min}	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120	10	0	-10	-20	-30	-40	-50	-80	-120
				$\sigma_{Ed} = 0{,}75 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}5 \cdot f_y(t)$									$\sigma_{Ed} = 0{,}25 \cdot f_y(t)$								
S650	MC	−20	40	250	230	160	110	75	55	35	15	5	250	250	250	250	185	130	95	35	10	250	250	250	250	250	250	250	130	50
S690 a	Q	0	40	140	100	70	45	35	25	15	5	-	250	235	165	120	85	60	45	20	5	250	250	250	250	250	205	155	70	30
	Q	−20	30	205	140	100	70	45	35	25	10	-	250	250	235	165	120	85	60	25	10	250	250	250	250	250	250	205	90	35
	QL	−20	40	250	205	140	100	70	45	35	10	5	250	250	250	235	165	120	85	35	10	250	250	250	250	250	250	250	120	45
	QL	−40	30	250	250	205	140	100	70	45	15	5	250	250	250	250	235	165	120	45	15	250	250	250	250	250	250	250	155	55
	QL1	−40	40	250	250	250	205	140	100	70	25	5	250	250	250	250	250	235	165	60	20	250	250	250	250	250	250	250	205	70
	QL1	−60	30	250	250	250	250	205	140	100	35	10	250	250	250	250	250	250	235	85	25	250	250	250	250	250	250	250	250	90
S700	MC	−20	40	250	200	135	95	65	45	30	10	-	250	250	250	225	160	115	85	30	10	250	250	250	250	250	250	250	115	45

a For ordering products made of S690 steels the test temperature T_{KV} for the selected subgrade shall be specified.

Linear interpolation may be used in applying Table 4.3. Most applications require σ_{Ed} values between $\sigma_{Ed} = 0{,}75\ f_y(t)$ and $\sigma_{Ed} = 0{,}50\ f_y(t)$.

Where a dash is shown in Table 4.3 the result will be less than 5 mm and the background design procedure is not valid. These steel grades and qualities should not be used under these conditions unless specialist advice is sought.

Table 4.3 has been derived for the Charpy energy values *KV* for specimens in the rolling direction of the product. Charpy energy values *KV* for specimens perpendicular to the rolling direction of the product can be lower than the values for specimens in the direction of the rolling. If required, minimum Charpy energy values perpendicular to the rolling direction can be specified in accordance with product standard options.

NOTE 1 For elements under compression stress see 4.1 (4).

NOTE 2 All the sizes shown in Table 4.3 are not necessarily included in the relevant product standards.

NOTE 3 The tabulated values are for structural details that conform to Detail Categories of EN 1993-1-9. For more complex geometries and reduction factors due to fabrication see 4.2.2.3.

4.2.2.3 Details not conforming to EN 1993-1-9 and complex joints

(1) For details not covered by detailed tables related to nominal stress methods according to EN 1993-1-9 and joints which in light of brittle fracture are complex in terms of stress states, fabrication or inspection for Execution Class 1 and 2 in non-fatigue cases, a simple approach to avoid evaluation by using Fracture Mechanics in 4.2.3 may be applied.

NOTE Complex joints are joints where tensile stresses are present in more than one plane due to the applied loading (or restraint due to joint geometry).

(2) As a simple approach, the reduction factors in Table 4.5 may be applied to the permissible values of element thickness in Table 4.3.

(3) The weighted sum of the factors $W_c = W_{ca} + W_{cb} + W_{cc} + W_{cd} + W_{ce}$ given in Table 4.4 should be used for the determination of the reduction factors according to Table 4.5.

(4) In addition to requirements for Charpy energy values KV in the direction of the rolling according to Table 4.3 or subclause 4.5, for complex joints Charpy energy values KV in the transverse rolling direction may be tested and the avoidance of lamellar tearing shall be considered.

NOTE 1 The values for the reduction factors are given in Table 4.5, unless the National annex defines other values.

NOTE 2 For spade details under quasi-static loads, specific rules are provided in Annex A.

(5) Table 4.4 should not be applied for details given in the tables belonging to the nominal stress method of EN 1993-1-9.

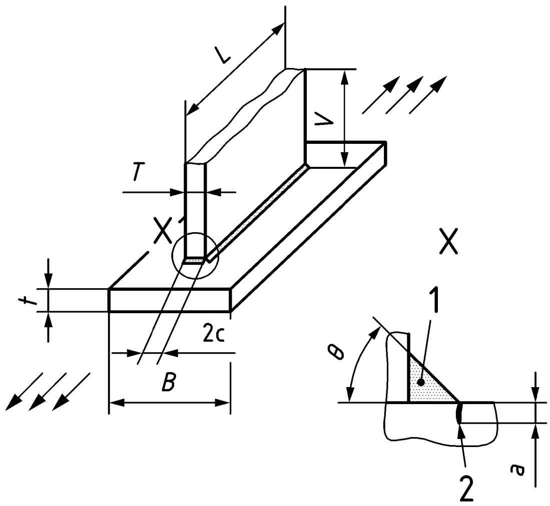
(6) For elements in EXC3 not subject to fatigue actions, this approach should be applied. The minimum thicknesses from Table 4.2 and from the approach in this subclause may be adopted for complex joints.

Table 4.4 — Selection of weighting factors for detail complexity

	Factor of influence	**Level of influencing parameters**	***W*-value**
a)	Degree of triaxiality due to nominal stresses	Uniaxial (Reference, see e.g. Figure 4.2)	$W_{ca} = 0$
		Biaxial	$W_{ca} = 2$
		Multiaxial, see e.g. Figure 4.3	$W_{ca} = 5$
b)	Degree of stress concentration	Medium (Reference, see e.g. Figure 4.2)	$W_{cb} = 0$
		High	$W_{cb} = 2$
c)	Accessibility of NDT during fabrication	Normal (Reference, see e.g. Figure 4.2)	$W_{cc} = 0$
		Difficult, see e.g. Figure 4.3	$W_{cc} = 1$
d)	Fabrication of holes	No holes (Reference, see e.g. Figure 4.2)	$W_{cd} = 0$
		Drilled	$W_{cd} = 0$
		Punched	$W_{cd} = 1$
e)	Level of residual stresses σres	σres < 0,5 fy (after stress relieving due to heat treatment)	$W_{ce} = -1$
		0,75 fy < σres < 1,0 fy (Reference, see e.g. Figure 4.2)	$W_{ce} = 0$

Table 4.5 — Reduction factors

Weighting factors	$-1 \leq Wc \leq 2$	$3 \leq Wc \leq 4$	$5 \leq Wc \leq 6$	$7 \leq Wc \leq 9$
Reduction Factors	1,0	0,75	0,50	0,35



Key

1 fillet weld

2 semi-elliptical surface crack

Figure 4.2 — Example of reference detail

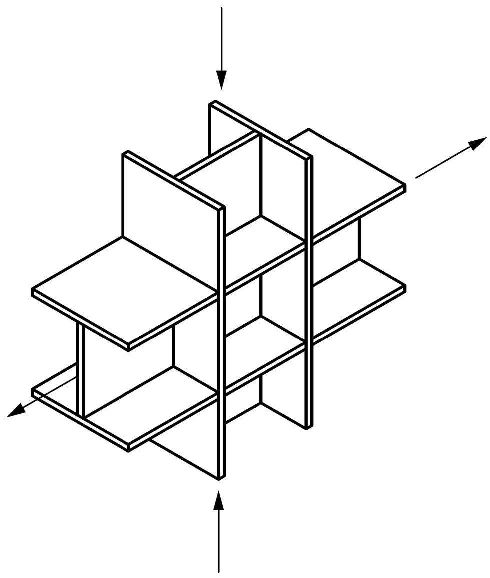


Figure 4.3 — Example detail for multiaxial loading and with difficult accessibility for NDT depending on the member sizes.

4.2.3 Evaluation using fracture mechanics

(1) If more rigorous methods are needed to obtain results which are more refined than those given in 4.2.2, then a specific verification should be carried out using fracture mechanics or fracture mechanics assisted by fracture tests on large-scale test specimens.

(2) Using fracture mechanics or fracture mechanics assisted by testing, the potential failure mechanism should be modelled assuming residual stresses where appropriated and using a suitable flaw that reduces the net section of the material thus making it more susceptible to failure by fracture of the reduced section.

(3) The flaw should meet the following requirements:

- location and shape should be appropriate for the structural detail considered. The fatigue classification tables in EN 1993-1-9 may be used for guidance on appropriate crack positions.
- for members not susceptible to fatigue, the size of the flaw should be the maximum likely to have been left uncorrected in inspections carried out to EN 1090. The assumed flaw should be located at the position of the most adverse stress concentration.
- for members susceptible to fatigue, the size of the flaw should consist of an initial flaw grown by fatigue. The size of the initial crack should be chosen such that it represents the minimum value detectable by the inspection methods used in accordance with EN 1090. The crack growth from fatigue should be calculated with an appropriate fracture mechanics model using loads experienced during the design safe working life or an inspection interval (as relevant).

(4) For numerical evaluation using fracture mechanics, the toughness requirement and the design toughness property of the materials may be expressed in terms of *CTOD* values, *J*-integral values, K_{IC} values, or *KV*-values. A comparison should be made using suitable fracture mechanics methods.

(5) Alternatively to (4), the following condition for the reference temperature may be met:

$$T_{Ed} \geq T_{Rd} \quad (4.9)$$

where

T_{Rd} is the temperature at which a safe level of fracture toughness can be relied upon under the conditions being evaluated

(6) If a structural detail, whether subjected to fatigue or not, cannot be allocated to either a specific detail category from EN 1993-1-9 or one of complex joints according to 4.2.2.3 or if more rigorous methods are needed to obtain results which are more refined than those given in Table 4.2 or Table 4.3, then a specific verification should be carried out using fracture tests on large scale test specimens.

NOTE The conditions to carry out the tests, the procedure for the large-scale testing and the evaluation of the test results can be defined in the National annexes.

(7) Large scale testing evaluation may be carried out using one or more large-scale test specimens. To achieve realistic results, the specimens should be constructed and loaded in a similar way to the actual structure.

NOTE The numerical evaluation of the test results can be undertaken using the methodology given in EN 1990:2002, Annex D.

4.3 Materials with additional fracture toughness requirements in relation to upper shelf

(1) In addition to the provisions given in FprEN 1993-1-1:2022, 5.2 and in 4.2 of this document, for material thickness t > 30mm for steel grade S275, S355 and for S235 where specified below, the following requirement should apply:

- For EXC1 the minimum toughness requirements should be JR.
- For EXC2 and for statically loaded steel work in EXC3, the minimum toughness requirements should be J0.
- For fatigue loaded steelwork in EXC3, the minimum toughness requirements should be J2 for steel grade S235, S275 and S355.
- For EXC4, fine grain steels should be used.

(2) The design against brittle fracture according to Clause 4.2 could lead to higher minimum toughness requirements than mentioned in (1). In such cases the higher of both toughness requirements should be used.

(3) Where a further test is required, a minimum energy KV_{us} should not be less than 100 J in a Charpy-V-notch impact test at room temperature. For fine grain steels, no test of KV_{us} is necessary.

NOTE 1 The National annex can determine the scope of application, provide alternative requirements or alternative procedures for 4.3. This includes the conditions where the further test in paragraph (3) is required.

NOTE 2 Fine grain steels are steels with a ferritic grain size equivalent index of ≥ 6, see EN ISO 643.

(4) For elements not subject to tension stresses, the provisions of 4.3 do not apply.

4.4 Materials with additional fracture toughness requirements in relation to seismic design

(1) For structures where seismic design is required, the following requirements should apply to dissipative elements:

- For structures classified as DC1 with regards to Seismic Ductility Class according to EN 1998, the minimum toughness requirements should be J2.
- For structures classified as DC2 or DC3, fine grain steels should be used.

(2) The design against brittle fracture according to Clause 4.2 could lead to higher minimum toughness requirements than mentioned in (1). In such cases the higher of both toughness requirements should be used.

(3) Where a further test is required, a minimum energy KV_{us} should not be less than 125 J in a Charpy-V-notch impact test at room temperature. For fine grain steels, no test of KV_{us} is necessary.

NOTE 1 The National annex can determine alternative requirements or alternative procedures for 4.4. This includes the conditions where the further test in clause (3) is required.

NOTE 2 Fine grain steels are steels with a ferritic grain size equivalent index of ≥ 6, see EN ISO 643.

4.5 Additional material requirements when welding in cold formed zones

(1) For welding in cold-formed zones, additional material requirements shall be taken into account.

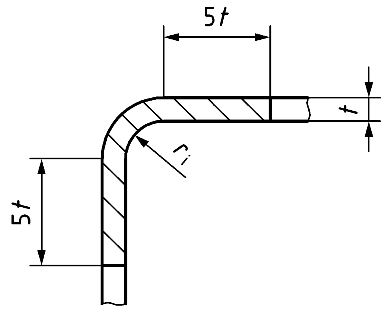
(2) The cold-formed zone includes the corner and a distance of 5*t* either side as depicted in the figure in Table 4.6. Welding shall be permitted in this zone provided the steel grade is lower or equal to S460 and one of the following conditions are satisfied:

- the cold-formed zones are normalized after cold forming but before welding,
- the *r/t*-ratio and the thickness satisfy the relevant values obtained from Table 4.6.

(3) Cold-formed stress relieved rectangular hollow sections should be treated as cold-formed sections.

Table 4.6 — Conditions for welding cold-formed corners and adjacent material

r_i/t	Strain due to cold forming [%]	Maximum thickness t [mm]		
		Generally		Fully killed - / Aluminium-killed steel (Al ≥ 0,02 %)
		Predominantly static loading	Where fatigue predominates	
≥ 25	≤ 2	any	any	any
≥ 10	≤ 5	any	16	any
≥ 3,0	≤ 14	24	12	24
≥ 2,0	≤ 20	12	10	12
≥ 1,5	≤ 25	8	8	10
≥ 1,0	≤ 33	4	4	6



NOTE For cold-formed hollow sections of steel grades up to and equal S460 according to EN 10219 which do not satisfy the inside corner-to-thickness (r/t) limits in Table 4.6, welding in the cold-formed corners and adjacent distances of 5*t* from the corners can be carried out if the following are satisfied:

- thickness t ≤ 12,5 mm;
- the steel is aluminium killed;
- the steel quality is J2H, K2H, MH, MLH, NH or NLH;
- the chemical analysis meets the following limits: C ≤ 0,18 %, *P* ≤ 0,02 % and S ≤ 0,012 %.

(4) Welding in cold-formed zones may be used if it can be demonstrated by tests that welding is acceptable for that particular application.

5 Avoidance of lamellar tearing by the specification of through thickness properties

5.1 General

(1) The following aspects should be considered in the selection of steel assemblies or connections to safeguard against lamellar tearing:

- the criticality of the location in terms of applied tensile stress and the degree of redundancy;
- the strain in the through-thickness direction in the element to which the connection is made.

NOTE 1 This strain arises from the shrinkage of the weld metal as it cools. It is greatly increased where free movement is restrained by other portions of the structure.

- the nature of the joint detail, in particular welded cruciform, tee and corner joints with full penetration butt welds and fillet welds.

NOTE 2 For example, at the locations shown in Figure 5.1, the horizontal plate might have poor ductility in the through-thickness direction. Lamellar tearing is most likely to arise if the strain in the connection acts through the thickness of the material, which occurs if the fusion face is roughly parallel to the surface of the material and the induced shrinkage strain is perpendicular to the direction of rolling of the material. The heavier the weld, the greater is the susceptibility.

- chemical properties of transversely stressed material.

NOTE 3 High sulphur levels in particular, even if significantly below normal steel product standard limits, can increase the risk of lamellar tearing.

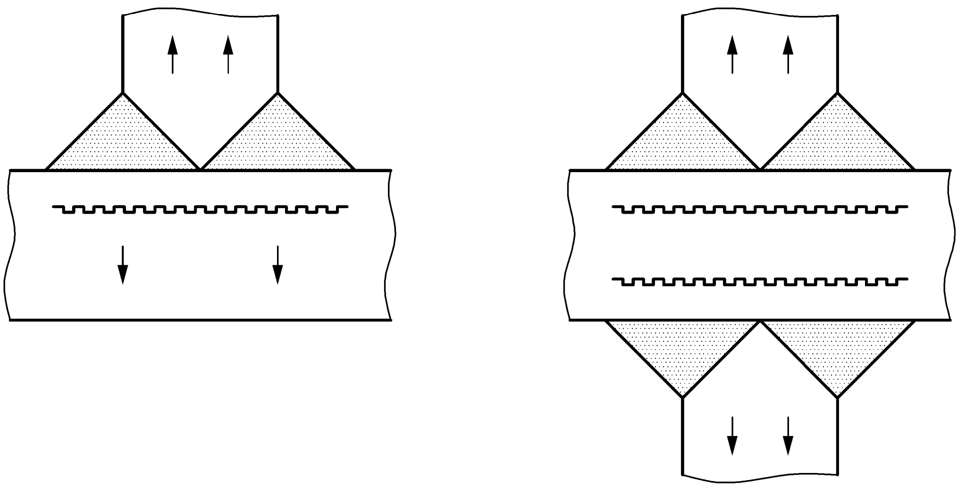


Figure 5.1 — Lamellar tearing

(2) The choice of quality option should be selected from Table 5.1 depending on the consequences of lamellar tearing. Irrespective of which option is adopted, the specification of through thickness properties may be combined with pre- and /or post-fabrication inspection.

(3) The use of Option 1 in Table 5.1 is recommended.

NOTE The National annex can stipulate the use of Option 2.

Table 5.1 — Choice of quality option

Option	Application of guidance	Note
1	General application to all prefabricated components independently on the material and end use.	The specification of through thickness properties from EN 10164 is recommended. As an alternative, ultrasonic inspection prior to fabrication in accordance with EN 10160 is permitted.
2	Application restricted to cases of high risks associated to lamellar tearing.	Post fabrication inspection should be used to identify whether lamellar tearing has occurred in the weld zone as indicated in Figure 5.1 provided the minimum hold times after welding have been observed.

(4) The susceptibility of the material should be determined by measuring the through-thickness ductility quality to EN 10164, which is expressed in terms of quality classes identified by Z-values.

NOTE Guidance on the avoidance of lamellar tearing during welding is given in EN 1011-2 including the sulphur content of the parent metal.

5.2 Procedure

(1) Lamellar tearing may be neglected if the condition in Formula (5).1) is satisfied:

$$Z_{Ed} \leq Z_{Rd} \quad (5.1)$$

where

Z_{Ed} is the required design Z-value resulting from the magnitude of strains from restrained metal shrinkage under the weld beads.

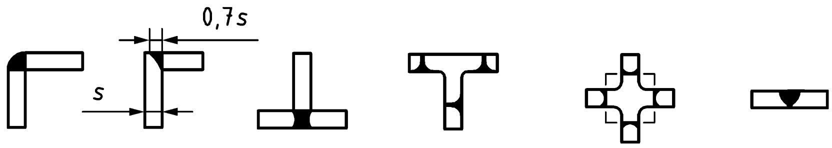
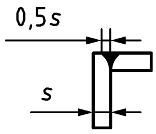
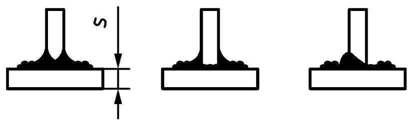
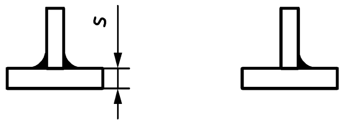
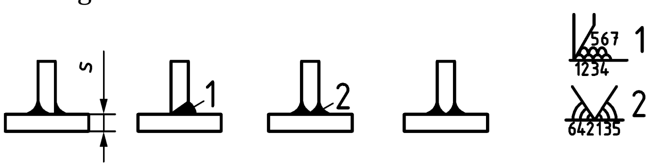
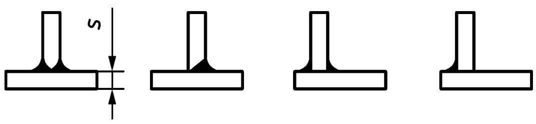
Z_{Rd} is the available design Z-value for the material according to EN 10164, i.e. *Z15*, *Z25* or *Z35*.

(2) The required design value Z_{Ed} may be determined using Formula (5).2):

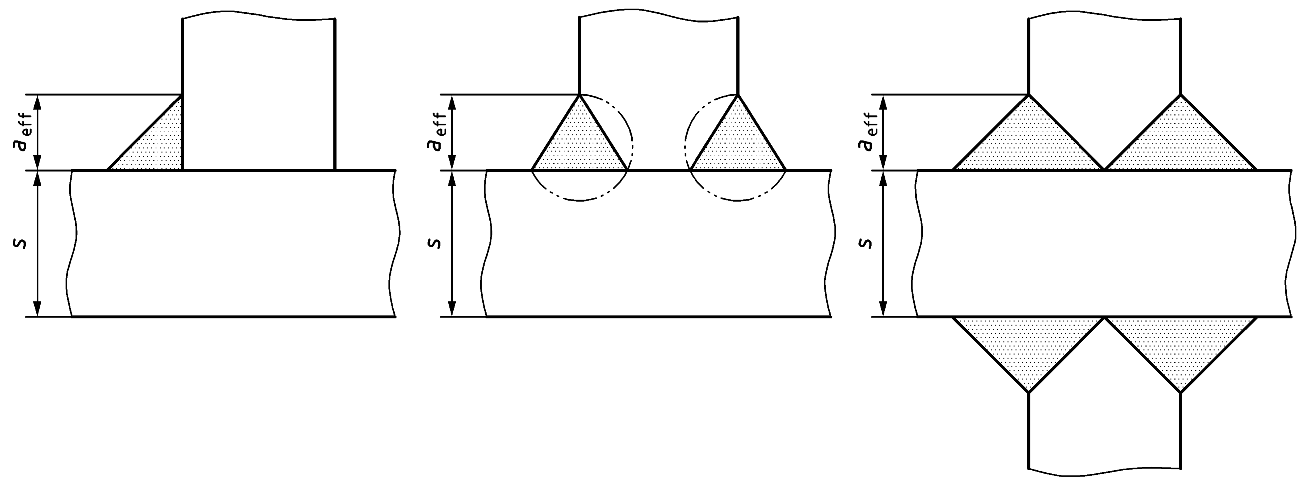
$$Z_{Ed} = Z_a + Z_b + Z_c + Z_d + Z_e \quad (5.2)$$

in which Z_a, Z_b, Z_c, Z_d and Z_e are as given in Table 5.2.

Table 5.2 — Criteria affecting the design value of Z_{Ed}

	Factor of influence	**Influencing parameters**		***Z* value**
a)	Weld depth relevant for straining from metal shrinkage	Effective weld depth a_{eff} (see Figure 5.2)		Z_i
		$a_{eff} \leq 7mm$		$Z_a = 0$
		$7 < a_{eff} \leq 10mm$		$Z_a = 3$
		$10 < a_{eff} \leq 20mm$		$Z_a = 6$
		$20 < a_{eff} \leq 30mm$		$Z_a = 9$
		$30 < a_{eff} \leq 40mm$		$Z_a = 12$
		$40 < a_{eff} \leq 50mm$		$Z_a = 15$
		$a_{eff} > 50$		$Z_a = 15$
b)	Shape and position of welds in T- and cruciform- and corner-connections			$Z_b = -25$
		corner joints		$Z_b = -10$
		single run fillet welds $Z_a = 0$ or fillet welds with $Z_a > 1$ with buttering with low strength weld material		$Z_b = -5$
		multi run fillet welds		$Z_b = 0$
		partial and full penetration plus fillets welds	with appropriate welding sequence to reduce shrinkage effects 	$Z_b = 3$
		partial and full penetration welds plus fillet welds near corners		$Z_b = 5$
		corner joints		$Z_b = 8$
c)	Effect of material thickness on restraint to shrinkage	$s \leq 10mm$		$Z_c = 2$[a]
		$10 < s \leq 20mm$		$Z_c = 4$ [a]
		$20 < s \leq 30mm$		$Z_c = 6$ [a]
		$30 < s \leq 40mm$		$Z_c = 8$ [a]

		$40 < s \leq 50$mm		$Z_c = 10$ [a]
		$50 < s \leq 60$mm		$Z_c = 12$ [a]
		$60 < s \leq 70$mm		$Z_c = 15$ [a]
		$s > 70$		$Z_c = 15$ [a]
d)	Remote restraint of shrinkage after welding by other portions of the structure	Low restraint:	Free shrinkage possible (e.g. T-joints)	$Z_d = 0$
		Medium restraint:	Free shrinkage restricted (e.g. diaphragms in box girders)	$Z_d = 3$
		High restraint:	Free shrinkage not possible (e.g. stringers in orthotropic deck plates)	$Z_d = 5$
e)	Influence of preheating	Without preheating		$Z_e = 0$
		Preheating ≥ 100°C		$Z_e = -8$
[a] May be reduced by 50 % when the material is in compression in the through-thickness direction due to predominantly static loads.				



NOTE Only one effective weld depth per detail is to be considered.

Figure 5.2 — Effective weld depth a_{eff} for shrinkage

(3) The appropriate Z_{Rd}-Quality class according to EN 10164 may be obtained by applying an available design Z-value Z_{Rd}.

NOTE For design Z-values Z_{Rd}, see FprEN 1993-1-1 and EN 1993-2 to EN 1993-6.

Annex A
(informative)

Specific rules for gusset plates with cut-outs in spade details

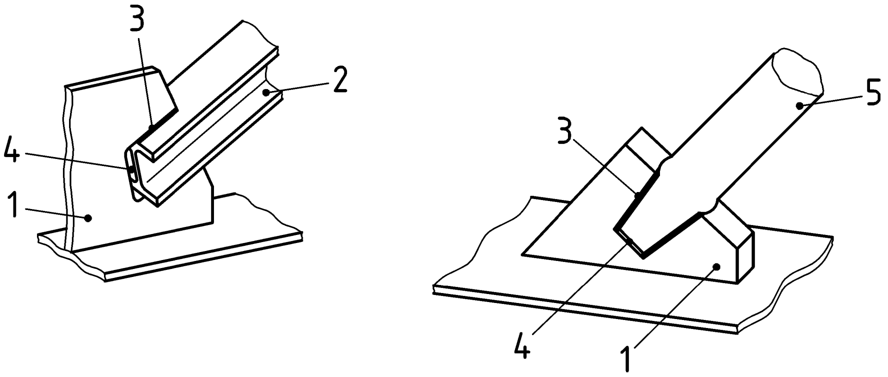
A.1 Use of this annex

(1) This informative annex contains the provisions for the selection of gusset plate material in spade details where the profile section is inserted into a cut-out in the gusset plate.

NOTE National choice on the application of this informative annex is given in the national annex. If the national annex contains no information on the application of this informative annex, it can be used.

A.2 Scope and field of application

(1) This informative Annex covers the specific selection process for welded spade details made of circular hollow sections, solid bars and rolled H- or I-profiles in accordance with Figure A.1 subject to predominantly static loading only.



Key

Gusset plate

Inserted H-profile

Weld

Gap

Inserted solid bar

Figure A.1 — Examples for spade details with different design.

(2) The rules have been derived for details with a gap at the end of the inserted profile, where load transfer only occur at longitudinal welds on both side of the inserted profile. However, the rules are conservative for cases where the gap length (L_{Sp}) is reduced to a minimum.

A.3 Selection process

(1) The choice of material in relation to spade details is concerned with the gusset plates. It is dependent on:

— gusset plate steel grade, see 1.1(4),

— minimum steel temperature, see 4.2.1,

— maximum applied nominal stress σ_{Ed}, see 4.2.1,

— main geometric parameters, see A.4 instead of 4.2.3,

— inhomogeneity of toughness, and

— safety allowance, see 4.2.1.

A.4 Determination of main geometric parameters and maximum applied stress σ_{Ed}

(1) The relevant geometric parameters for the choice of material for spade details are shown in Figure A.2. The main values and related values are as follows:

— Thickness of attached gusset plate t

— Net cross section at one side of the gusset

plate measured from the gap, see section A-A w_i^*

— Width of the gap H related to w_1^* or w_2^* $H/2w_i^*$

— Length of the weld L longitudinal to inserted profile related to w_1^* or w_2^* L/w_i^*

NOTE For the following simplified method using tabulated values share notches like cracks are assumed at the edges of the gap.

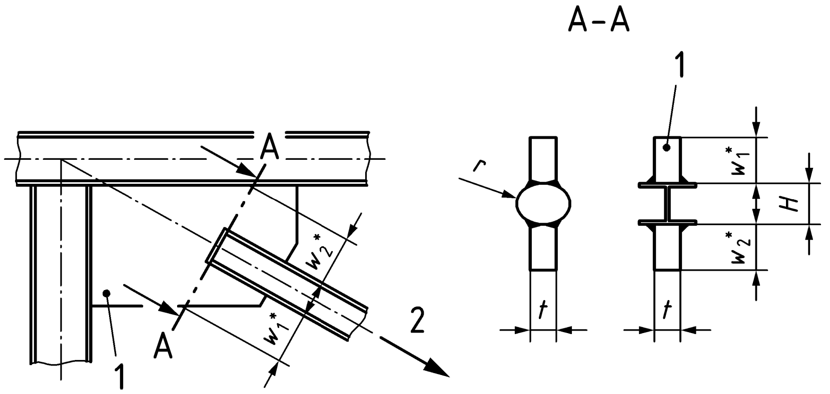
(2) The main design values of the nominal stress σ_{Ed} resulting from design value of the force D_{Ed} in the inserted profile should be calculated in section A-A shown in Figure A.2 using net cross section, see Formula (A.1).

$$\sigma_{Ed} = \frac{D_{Ed}}{A_{net}} = \frac{D_{Ed}}{\left(w_1^* + w_2^*\right) \cdot t} \quad [\text{N/mm}^2] \qquad \text{(A.1)}$$

D_{Ed} Force in the profile inserted in the gusset plate

A_{net} net cross section in section A-A

(3) The use of Formula (A.1) shall be limited to a maximum net width w_1^* and w_2^* smaller or equal than 1,5 times the minimum net width w_1^* or w_2^*.



a) Example of a spaded joint b) Geometric Parameters in cross section A-A

Key

Gusset plate

Force in the inserted profile

Figure A.2 — Definition of the geometric parameters and location of the main net cross section A-A.

A.5 Determination of maximum allowable geometric parameters

(1) The relevant geometric parameter for the choice of material for spade details is the net cross section at one side of the gusset plate measured from the gap w_i*. The width w_i* should be determined for both sides w_1* and w_2*.

(2) An orientation for normal, favourable and un-favourable values of different geometric parameters of spaded details may be taken from Table A.1.

(3) Table A.2 to Table A.7 give the maximum permissible values of the width of the gusset plate on one side of the gap w_i*. The widths are presented in terms of three stress levels expressed as proportions of the nominal yield strength:

$\sigma_{Ed} = 0{,}75\, f_y(t)$ [N/mm²]

$\sigma_{Ed} = 0{,}50\, f_y(t)$ [N/mm²]

$\sigma_{Ed} = 0{,}25\, f_y(t)$ [N/mm²]

where $f_y(t)$ may be determined as mentioned in 4.2.2.2.

Each table is related to specific geometric parameters and related parameters defined in A.4. Furthermore, the tabulated values are given in terms of a choice of seven reference temperatures T_{Ed}: +10, 0, −10, −20, −30, −40 and −50°C.

(4) Linear interpolation may be used in applying Table A.2 to Table A.7.

(5) Extrapolations beyond the extreme values of the stresses indicated in Table A.2 till Table A.7 are not valid.

(6) Details with geometric parameters which do not comply with normal values or better should not be adopted using Table A.2 to Table A.7 inclusive.

(7) Details whose geometric parameters lie between normal and favourable values should be determined by using table for normal values.

(8) Details whose geometric parameters lie between normal and un-favourable should have the toughness determined using fracture mechanics.

Table A.1 — Combination of geometric parameters

parameters		un-favourable value	usual value	favourable value
w_i*	**[mm]**	**300**	**130**	**80**
L/w_i*	**[-]**	**≥ 0,8**	**≥ 1,3**	**≥ 1,6**
$H/2w_i$*	**[-]**	**≤ 1,2**	**≤ 0,55**	**≤ 0,4**

Table A.2 — Maximum permissible values of the width of the gusset plate on one side of the gap w_i* [mm] for usual geometric parameters of spaded details according to Table A.1 and a thickness of the gusset plate $t \leq 120$ mm

$L/w_i^* \geq 1{,}3$ $H/2w_i^* \leq 0{,}55$ $t \leq 120$ mm																								
Steel grade	**Quality**	**KV**		**Reference Temperature T_{Ed} [°C]**																				
		T [°C]	**J_{min}**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**
				$\sigma_{Ed} = 0{,}75 \cdot f_y(t)$							$\sigma_{Ed} = 0{,}5 \cdot f_y(t)$							$\sigma_{Ed} = 0{,}25 \cdot f_y(t)$						
S235	JR	20	27	-	-	-	-	-	-	-	20	-	-	-	-	-	-	60	50	30	30	20	-	-
	J0	−0	27	-	-	-	-	-	-	-	50	30	20	-	-	-	-	140	90	60	50	30	30	20
	J2	−20	27	40	30	-	-	-	-	-	120	70	50	30	20	-	-	340	220	140	90	60	50	30
S275	JR	20	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	40	30	20	-	-	-
	J0	−0	27	-	-	-	-	-	-	-	40	20	-	-	-	-	-	120	80	50	40	30	20	-
	J2	−20	27	30	20	-	-	-	-	-	90	50	40	20	-	-	-	280	180	120	80	50	40	30
	M, N	−20	40	50	30	20	-	-	-	-	140	90	50	40	20	-	-	all	280	180	120	80	50	40
	ML, NL	−50	27	140	80	50	30	20	-	-	380	230	140	90	50	40	20	all	all	all	280	180	120	80
S355	JR	20	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	30	20	-	-	-	-
	J0	−0	27	-	-	-	-	-	-	-	20	-	-	-	-	-	-	80	50	40	30	20	-	-
	J2	−20	27	-	-	-	-	-	-	-	50	30	20	-	-	-	-	190	120	80	50	40	30	-
	K2, M, N	−20	40	30	-	-	-	-	-	-	80	50	30	20	-	-	-	310	190	120	80	50	40	30
	ML, NL	−50	27	80	40	30	-	-	-	-	230	140	80	50	30	20	-	all	all	310	190	120	80	50
S420	M, N	−20	40	-	-	-	-	-	-	-	50	40	20	-	-	-	-	240	150	90	60	40	30	20
	ML, NL	−50	27	50	30	-	-	-	-	-	160	90	50	40	20	-	-	all	380	240	150	90	60	40
S460	Q	−20	30	-	-	-	-	-	-	-	30	20	-	-	-	-	-	130	80	50	40	30	20	-
	M, N	−20	40	-	-	-	-	-	-	-	50	30	20	-	-	-	-	200	130	80	50	40	30	20

	QL	−40	30	20	-	-	-	-	-	-	80	50	30	20	-	-	-	330	200	130	80	50	40	30
	ML, NL	−50	27	40	20	-	-	-	-	-	130	80	50	30	20	-	-	all	330	200	130	80	50	40
	QL1	−60	30	70	40	20	-	-	-	-	220	130	80	50	30	20	-	all	all	330	200	130	80	50
S690	Q	0	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	30	-	-	-	-	-
	Q	−20	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	40	30	-	-	-	-
	QL	−20	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	60	40	30	-	-	-
	QL	−40	30	-	-	-	-	-	-	-	30	-	-	-	-	-	-	150	90	60	40	30	-	-
	QL1	−40	40	-	-	-	-	-	-	-	50	30	-	-	-	-	-	250	150	90	60	40	30	-
	QL1	−60	30	20	-	-	-	-	-	-	80	50	30	-	-	-	-	all	250	150	90	60	40	30

Where a dash is shown in this table the result will be less than 5 mm and the background design procedure is not valid. These steel grades and qualities should not be used under these conditions unless specialist advice is sought. Where the word all is shown in these tables no limitation of the gusset plate width w_i* is necessary and all widths are allowed to use.

For elements under compression stress a value of σ_{Ed} = 0,25 $f_y(t)$ is recommended.

This table has been derived for the Charpy energy values *KV* for specimens in the rolling direction of the product. Charpy energy values *KV* for specimens perpendicular to the rolling direction of the product specified in accordance with product standard options may be taken as equivalent values.

Table A.3 — Maximum permissible values of the width of the gusset plate on one side of the gap wi* [mm] for usual geometric parameters of spaded details according to Table A.1 and a thickness of the gusset plate t ≤ 80 mm

$L/w_i^* \geq 1{,}3$ $H/2w_i^* \leq 0{,}55$ $t \leq 80$ mm																								
Steel grade	Quality	KV		Reference Temperature T_{Ed} [°C]																				
		T [°C]	J_{min}	10	0	-10	-20	-30	-40	-50	10	0	-10	-20	-30	-40	-50	10	0	-10	-20	-30	-40	-50
				$\sigma_{Ed} = 0{,}75 \cdot f_y(t)$							$\sigma_{Ed} = 0{,}5 \cdot f_y(t)$							$\sigma_{Ed} = 0{,}25 \cdot f_y(t)$						
S235	JR	20	27	-	-	-	-	-	-	-	30	20	-	-	-	-	-	80	60	40	30	20	20	-
	J0	−0	27	20	-	-	-	-	-	-	60	40	30	20	-	-	-	190	120	80	60	40	30	20
	J2	−20	27	60	40	20	-	-	-	-	150	100	60	40	30	20	-	all	290	190	120	80	60	40
S275	JR	20	27	-	-	-	-	-	-	-	20	-	-	-	-	-	-	70	50	30	30	20	-	-
	J0	−0	27	-	-	-	-	-	-	-	40	30	20	-	-	-	-	150	100	70	50	30	30	20
	J2	−20	27	40	20	-	-	-	-	-	110	70	40	30	20	-	-	370	240	150	100	70	50	30
	M, N	−20	40	70	40	20	-	-	-	-	190	110	70	40	30	20	-	all	370	240	150	100	70	50
	ML, NL	−50	27	190	110	70	40	20	-	-	all	310	190	110	70	40	30	all	all	all	370	240	150	100
S355	JR	20	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	30	20	20	-	-	-
	J0	−0	27	-	-	-	-	-	-	-	30	20	-	-	-	-	-	110	70	50	30	20	20	-
	J2	−20	27	20	-	-	-	-	-	-	70	40	30	20	-	-	-	260	160	110	70	50	30	20
	K2, M, N	−20	40	40	20	-	-	-	-	-	110	70	40	30	20	-	-	all	260	160	110	70	50	30
	ML, NL	−50	27	100	60	40	20	-	-	-	310	180	110	70	40	30	20	all	all	all	260	160	110	70
S420	M, N	−20	40	20	-	-	-	-	-	-	80	50	30	20	-	-	-	320	200	130	80	50	40	30
	ML, NL	−50	27	70	40	20	-	-	-	-	220	130	80	50	30	20	-	all	all	320	200	130	80	50
S460	Q	−20	30	-	-	-	-	-	-	-	40	20	-	-	-	-	-	170	110	70	50	30	20	-
	M, N	−20	40	20	-	-	-	-	-	-	60	40	20	-	-	-	-	280	170	110	70	50	30	20
	QL	−40	30	30	20	-	-	-	-	-	100	60	40	20	-	-	-	all	280	170	110	70	50	30
	ML, NL	−50	27	50	30	20	-	-	-	-	180	100	60	40	20	-	-	all	all	280	170	110	70	50

	QL1	−60	30	90	50	30	20	-	-	-	300	180	100	60	40	20	-	all	all	all	280	170	110	70
S690	Q	0	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	30	20	-	-	-	-
	Q	−20	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80	50	30	20	-	-	-
	QL	−20	40	-	-	-	-	-	-	-	20	-	-	-	-	-	-	130	80	50	30	20	-	-
	QL	−40	30	-	-	-	-	-	-	-	40	20	-	-	-	-	-	210	130	80	50	30	20	-
	QL1	−40	40	-	-	-	-	-	-	-	60	40	20	-	-	-	-	350	210	130	80	50	30	20
	QL1	−60	30	30	-	-	-	-	-	-	110	60	40	20	-	-	-	all	350	210	130	80	50	30

Where a dash is shown in this table the result will be less than 5 mm and the background design procedure is not valid. These steel grades and qualities should not be used under these conditions unless specialist advice is sought. Where the word all is shown in these tables no limitation of the gusset plate width w_i* is necessary and all widths are allowed to use.

For elements under compression stress a value of σ_{Ed} = 0,25 $f_y(t)$ is recommended.

This table has been derived for the Charpy energy values *KV* for specimens in the rolling direction of the product. Charpy energy values *KV* for specimens perpendicular to the rolling direction of the product specified in accordance with product standard options may be taken as equivalent values.

Table A.4 — Maximum permissible values of the width of the gusset plate on one side of the gap w_i* [mm] for usual geometric parameters of spaded details according to Table A.1 and a thickness of the gusset plate $t \leq 40$ mm

$L/w_i^* \geq 1{,}3$ $H/2w_i^* \leq 0{,}55$ $t \leq 40$ mm																								
Steel grade	**Quality**	**KV**		**Reference Temperature T_{Ed} [°C]**																				
		T [°C]	**J_{min}**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**
				$\sigma_{Ed} = 0{,}75 \cdot f_y(t)$							$\sigma_{Ed} = 0{,}5 \cdot f_y(t)$							$\sigma_{Ed} = 0{,}25 \cdot f_y(t)$						
S235	JR	20	27	20	-	-	-	-	-	-	60	40	30	20	-	-	-	190	120	80	60	40	30	30
	J0	−0	27	50	30	20	-	-	-	-	150	90	60	40	30	20	-	all	280	190	120	80	60	40
	J2	−20	27	150	90	50	30	20	-	-	380	240	150	90	60	40	30	all	all	all	280	190	120	80
S275	JR	20	27	-	-	-	-	-	-	-	40	30	20	-	-	-	-	150	100	70	50	30	30	20
	J0	−0	27	40	20	-	-	-	-	-	100	70	40	30	20	-	-	360	230	150	100	70	50	30
	J2	−20	27	110	60	40	20	-	-	-	290	180	110	70	40	30	20	all	all	360	230	150	100	70
	M, N	−20	40	180	110	60	40	20	-	-	all	290	180	110	70	40	30	all	all	all	360	230	150	100
	ML, NL	−50	27	all	300	180	110	60	40	20	all	all	all	290	180	110	70	all	all	all	all	all	360	230
S355	JR	20	27	-	-	-	-	-	-	-	30	20	-	-	-	-	-	110	70	50	30	30	20	-
	J0	−0	27	20	-	-	-	-	-	-	70	40	30	20	-	-	-	260	160	110	70	50	30	30
	J2	−20	27	60	30	20	-	-	-	-	180	110	70	40	30	20	-	all	all	260	160	110	70	50
	K2, M, N	−20	40	100	60	30	20	-	-	-	290	160	110	70	40	30	20	all	all	all	260	160	110	70
	ML, NL	−50	27	290	170	100	60	30	20	-	all	all	290	180	110	70	40	all	all	all	all	all	260	160
S420	M, N	−20	40	60	40	20	-	-	-	-	210	120	70	40	30	20	-	all	all	310	200	130	80	50
	ML, NL	−50	27	190	110	60	40	20	-	-	all	340	210	120	70	40	30	all	all	all	all	310	200	130
S460	Q	−20	30	30	20	-	-	-	-	-	100	60	40	20	-	-	-	all	270	170	110	70	50	30
	M, N	−20	40	50	30	20	-	-	-	-	170	100	60	40	20	-	-	all	all	270	170	110	70	50

	QL	−40	30	90	50	30	20	-	-	-	280	170	100	60	40	20	-	all	all	all	270	170	110	70
	ML, NL	−50	27	150	90	50	30	20	-	-	all	280	170	100	60	40	20	all	all	all	all	270	170	110
	QL1	−60	30	270	150	90	50	30	20	-	all	all	280	170	100	60	40	all	all	all	all	all	270	170
S690	Q	0	40	-	-	-	-	-	-	-	20	-	-	-	-	-	-	130	80	50	30	20	-	-
	Q	−20	30	-	-	-	-	-	-	-	40	20	-	-	-	-	-	210	130	80	50	30	20	-
	QL	−20	40	20	-	-	-	-	-	-	60	40	20	-	-	-	-	340	210	130	80	50	30	20
	QL	−40	30	30	20	-	-	-	-	-	110	60	40	20	-	-	-	all	340	210	130	80	50	30
	QL1	−40	40	50	30	20	-	-	-	-	190	110	60	40	20	-	-	all	all	340	210	130	80	50
	QL1	−60	30	90	50	30	20	-	-	-	320	190	110	60	40	20	-	all	all	all	340	210	130	80

Where a dash is shown in this table the result will be less than 5 mm and the background design procedure is not valid. These steel grades and qualities should not be used under these conditions unless specialist advice is sought. Where the word all is shown in these tables no limitation of the gusset plate width w_i* is necessary and all widths are allowed to use.

For elements under compression stress a value of σ_{Ed} = 0,25 $f_y(t)$ is recommended.

This table has been derived for the Charpy energy values *KV* for specimens in the rolling direction of the product. Charpy energy values *KV* for specimens perpendicular to the rolling direction of the product specified in accordance with product standard options may be taken as equivalent values.

Table A.5 — Maximum permissible values of the width of the gusset plate on one side of the gap w_i* [mm] for favourable geometric parameters of spaded details according to Table A.1 and a thickness of the gusset plate $t \leq 80$ mm

$L/w_i^* \geq 1,6$ $H/2w_i^* \leq 0,4$ $t \leq 80$ mm																								
Steel grade	**Quality**	**KV**		**Reference Temperature T_{Ed} [°C]**																				
		T [°C]	**J_{min}**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**
				$\sigma_{Ed} = 0,75 \cdot f_y(t)$							$\sigma_{Ed} = 0,5 \cdot f_y(t)$							$\sigma_{Ed} = 0,25 \cdot f_y(t)$						
S235	JR	20	27	-	-	-	-	-	-	-	50	40	20	-	-	-	-	160	110	80	50	40	30	30
	J0	−0	27	40	30	-	-	-	-	-	120	70	50	40	20	-	-	380	240	160	110	80	50	40
	J2	−20	27	110	70	40	30	-	-	-	310	190	120	70	50	40	20	all	all	380	240	160	110	80
S275	JR	20	27	-	-	-	-	-	-	-	40	30	20	-	-	-	-	130	90	60	50	40	30	20
	J0	−0	27	30	-	-	-	-	-	-	90	50	40	30	20	-	-	310	200	130	90	60	50	40
	J2	−20	27	80	50	30	-	-	-	-	230	140	90	50	40	30	20	all	all	310	200	130	90	60
	M, N	−20	40	130	80	50	30	-	-	-	380	230	140	90	50	40	30	all	all	all	310	200	130	90
	ML, NL	−50	27	390	230	130	80	50	30	-	all	all	380	230	140	90	50	all	all	all	all	all	310	200
S355	JR	20	27	-	-	-	-	-	-	-	20	-	-	-	-	-	-	90	60	40	30	20	20	-
	J0	−0	27	-	-	-	-	-	-	-	50	30	20	-	-	-	-	210	130	90	60	40	30	20
	J2	−20	27	40	20	-	-	-	-	-	130	80	50	30	20	-	-	all	330	210	130	90	60	40
	K2, M, N	−20	40	70	40	20	-	-	-	-	220	130	80	50	30	20	-	all	all	330	210	130	90	60
	ML, NL	−50	27	210	120	70	40	20	-	-	all	380	220	130	80	50	30	all	all	all	all	330	210	130
S420	M, N	−20	40	40	30	-	-	-	-	-	150	90	50	40	20	-	-	all	all	250	160	100	70	50
	ML, NL	−50	27	130	70	40	30	-	-	-	all	260	150	90	50	40	20	all	all	all	all	250	160	100
S460	Q	−20	30	20	-	-	-	-	-	-	70	40	30	20	-	-	-	350	210	130	80	50	40	30
	M, N	−20	40	40	20	-	-	-	-	-	120	70	40	30	20	-	-	all	350	210	130	80	50	40

	QL	−40	30	60	40	20	-	-	-	-	210	120	70	40	30	20	-	all	all	350	210	130	80	50
	ML, NL	−50	27	100	60	40	20	-	-	-	360	210	120	70	40	30	20	all	all	all	350	210	130	80
	QL1	−60	30	190	100	60	40	20	-	-	all	360	210	120	70	40	30	all	all	all	all	350	210	130
S690	Q	0	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	60	40	30	20	-	-
	Q	−20	30	-	-	-	-	-	-	-	30	-	-	-	-	-	-	160	90	60	40	30	20	-
	QL	−20	40	-	-	-	-	-	-	-	40	30	-	-	-	-	-	260	160	90	60	40	30	20
	QL	−40	30	-	-	-	-	-	-	-	70	40	30	-	-	-	-	all	260	160	90	60	40	30
	QL1	−40	40	30	-	-	-	-	-	-	130	70	40	30	-	-	-	all	all	260	160	90	60	40
	QL1	−60	30	60	30	-	-	-	-	-	230	130	70	40	30	-	-	all	all	all	260	160	90	60

Where a dash is shown in this table the result will be less than 5 mm and the background design procedure is not valid. These steel grades and qualities should not be used under these conditions unless specialist advice is sought. Where the word all is shown in these tables no limitation of the gusset plate width w_i* is necessary and all widths are allowed to use.

For elements under compression stress a value of $\sigma_{Ed} = 0{,}25\, f_y(t)$ is recommended.

This table has been derived for the Charpy energy values *KV* for specimens in the rolling direction of the product. Charpy energy values *KV* for specimens perpendicular to the rolling direction of the product specified in accordance with product standard options may be taken as equivalent values.

Table A.6 — Maximum permissible values of the width of the gusset plate on one side of the gap w_i^* [mm] for favourable geometric parameters of spaded details according to Table A.1 and a thickness of the gusset plate $t \leq 40$ mm

$L/w_i^* \geq 1,6$ $H/2w_i^* \leq 0,4$ $t \leq 40$ mm																								
Steel grade	Quality	KV		Reference Temperature T_{Ed} [°C]																				
		T [°C]	J_{min}	10	0	-10	-20	-30	-40	-50	10	0	-10	-20	-30	-40	-50	10	0	-10	-20	-30	-40	-50
				$\sigma_{Ed} = 0,75 \cdot f_y(t)$							$\sigma_{Ed} = 0,5 \cdot f_y(t)$							$\sigma_{Ed} = 0,25 \cdot f_y(t)$						
S235	JR	20	27	40	30	20	-	-	-	-	120	70	50	30	30	20	-	380	250	170	110	80	60	40
	J0	−0	27	110	60	40	30	20	-	-	300	190	120	70	50	30	30	all	all	380	250	170	110	80
	J2	−20	27	310	180	100	60	40	30	20	all	all	300	190	120	70	50	all	all	all	all	380	250	170
S275	JR	20	27	30	20	-	-	-	-	-	90	50	40	30	20	-	-	310	200	140	90	60	50	40
	J0	−0	27	70	40	30	20	-	-	-	220	140	90	50	40	30	20	all	all	310	200	140	90	60
	J2	−20	27	220	130	70	40	30	20	-	all	370	220	140	90	50	40	all	all	all	all	310	200	140
	M, N	−20	40	370	220	130	70	40	30	20	all	all	370	220	140	90	50	all	all	all	all	all	310	200
	ML, NL	−50	27	all	all	370	220	130	70	40	all	all	all	all	370	220	140	all	all	all	all	all	all	all
S355	JR	20	27	-	-	-	-	-	-	-	50	30	20	-	-	-	-	210	140	90	60	40	30	30
	J0	−0	27	40	20	-	-	-	-	-	130	80	50	30	20	-	-	all	340	210	140	90	60	40
	J2	−20	27	110	70	40	20	-	-	-	370	220	130	80	50	30	20	all	all	all	340	210	140	90
	K2, M, N	−20	40	200	110	70	40	20	-	-	all	370	220	130	80	50	30	all	all	all	all	340	210	140
	ML, NL	−50	27	all	350	200	110	70	40	20	all	all	all	370	220	130	80	all	all	all	all	all	all	340
S420	M, N	−20	40	130	70	40	30	-	-	-	all	250	150	90	50	30	20	all	all	all	all	250	160	100
	ML, NL	−50	27	all	230	130	70	40	30	-	all	all	all	250	150	90	50	all	all	all	all	all	all	250
S460	Q	−20	30	60	30	20	-	-	-	-	200	120	70	40	30	20	-	all	all	350	220	140	90	60
	M, N	−20	40	100	60	30	20	-	-	-	350	200	120	70	40	30	20	all	all	all	350	220	140	90

	QL	−40	30	180	100	60	30	20	-	-	all	350	200	120	70	40	30	all	all	all	all	350	220	140
	ML, NL	−50	27	320	180	100	60	30	20	-	all	all	350	200	120	70	40	all	all	all	all	all	350	220
	QL1	−60	30	all	320	180	100	60	30	20	all	all	all	350	200	120	70	all	all	all	all	all	all	350
S690	Q	0	40	-	-	-	-	-	-	-	40	30	-	-	-	-	-	260	160	100	60	40	30	20
	Q	−20	30	20	-	-	-	-	-	-	70	40	30	-	-	-	-	all	260	160	100	60	40	30
	QL	−20	40	30	20	-	-	-	-	-	130	70	40	30	-	-	-	all	all	260	160	100	60	40
	QL	−40	30	50	30	20	-	-	-	-	220	130	70	40	30	-	-	all	all	all	260	160	100	60
	QL1	−40	40	100	50	30	20	-	-	-	390	220	130	70	40	30	-	all	all	all	all	260	160	100
	QL1	−60	30	190	100	50	30	20	-	-	all	390	220	130	70	40	30	all	all	all	all	all	260	160

Where a dash is shown in this table the result will be less than 5 mm and the background design procedure is not valid. These steel grades and qualities should not be used under these conditions unless specialist advice is sought. Where the word all is shown in these tables no limitation of the gusset plate width w_i* is necessary and all widths are allowed to use.

For elements under compression stress a value of σ_{Ed} = 0,25 $f_y(t)$ is recommended.

This table has been derived for the Charpy energy values *KV* for specimens in the rolling direction of the product. Charpy energy values *KV* for specimens perpendicular to the rolling direction of the product specified in accordance with product standard options may be taken as equivalent values.

Table A.7 — Maximum permissible values of the width of the gusset plate on one side of the gap w_i* [mm] for favourable geometric parameters of spaded details according to Table A.1 and a thickness of the gusset plate $t \leq 20$ mm

L/wᵢ* ≥ 1,6 H/2wᵢ* ≤ 0,4 t ≤ 20 mm																								
Steel grade	Quality	KV		Reference Temperature T_{Ed} [°C]																				
		T [°C]	J_{min}	10	0	-10	-20	-30	-40	-50	10	0	-10	-20	-30	-40	-50	10	0	-10	-20	-30	-40	-50
				$\sigma_{Ed} = 0,75 \cdot f_y(t)$							$\sigma_{Ed} = 0,5 \cdot f_y(t)$							$\sigma_{Ed} = 0,25 \cdot f_y(t)$						
S235	JR	20	27	140	90	50	30	20	-	-	all	250	160	100	70	40	30	all	all	all	330	220	150	110
	J0	−0	27	all	240	140	90	50	30	20	all	all	all	250	160	100	70	all	all	all	all	all	330	220
	J2	−20	27	all	all	all	240	140	90	50	all	all	all	all	all	250	160	all	all	all	all	all	all	all
S275	JR	20	27	100	60	30	20	-	-	-	300	180	120	70	50	30	20	all	all	all	270	180	120	90
	J0	−0	27	280	170	100	60	30	20	-	all	all	300	180	120	70	50	all	all	all	all	all	270	180
	J2	−20	27	all	all	280	170	100	60	30	all	all	all	all	300	180	120	all	all	all	all	all	all	all
	M, N	−20	40	all	all	all	280	170	100	60	all	all	all	all	all	300	180	all	all	all	all	all	all	all
	ML, NL	−50	27	all	all	all	all	all	280	170	all	all	all	all	all	all	all	all	all	all	all	all	all	all
S355	JR	20	27	50	30	20	-	-	-	-	180	110	70	40	30	20	-	all	all	290	190	120	80	60
	J0	−0	27	150	90	50	30	20	-	-	all	290	180	110	70	40	30	all	all	all	all	290	190	120
	J2	−20	27	all	270	150	90	50	30	20	all	all	all	290	180	110	70	all	all	all	all	all	all	290
	K2, M, N	−20	40	all	all	270	150	90	50	30	all	all	all	all	290	180	110	all	all	all	all	all	all	all
	ML, NL	−50	27	all	all	all	all	270	150	90	all	all	all	all	all	all	290	all	all	all	all	all	all	all
S420	M, N	−20	40	all	310	170	100	60	30	20	all	all	all	340	200	120	70	all	all	all	all	all	all	340
	ML, NL	−50	27	all	all	all	310	170	100	60	all	all	all	all	all	340	200	all	all	all	all	all	all	all
S460	Q	−20	30	240	140	80	40	30	20	-	all	all	270	160	100	60	30	all	all	all	all	all	290	190
	M, N	−20	40	all	240	140	80	40	30	20	all	all	all	270	160	100	60	all	all	all	all	all	all	290

	QL	−40	30	all	all	240	140	80	40	30	all	all	all	all	270	160	100	all	all	all	all	all	all	all
	ML, NL	−50	27	all	all	all	240	140	80	40	all	all	all	all	all	270	160	all	all	all	all	all	all	all
	QL1	−60	30	all	all	all	all	240	140	80	all	all	all	all	all	all	270	all	all	all	all	all	all	all
S690	Q	0	40	40	20	-	-	-	-	-	170	100	60	30	20	-	-	all	all	350	210	130	80	50
	Q	−20	30	80	40	20	-	-	-	-	300	170	100	60	30	20	-	all	all	all	350	210	130	80
	QL	−20	40	140	80	40	20	-	-	-	all	300	170	100	60	30	20	all	all	all	all	350	210	130
	QL	−40	30	250	140	80	40	20	-	-	all	all	300	170	100	60	30	all	all	all	all	all	350	210
	QL1	−40	40	all	250	140	80	40	20	-	all	all	all	300	170	100	60	all	all	all	all	all	all	350
	QL1	−60	30	all	all	250	140	80	40	20	all	all	all	all	300	170	100	all	all	all	all	all	all	all

Where a dash is shown in this table the result will be less than 5 mm and the background design procedure is not valid. These steel grades and qualities should not be used under these conditions unless specialist advice is sought. Where the word all is shown in these tables no limitation of the gusset plate width w_i* is necessary and all widths are allowed to use.

For elements under compression stress a value of σ_{Ed} = 0,25 $f_y(t)$ is recommended.

This table has been derived for the Charpy energy values *KV* for specimens in the rolling direction of the product. Charpy energy values *KV* for specimens perpendicular to the rolling direction of the product specified in accordance with product standard options may be taken as equivalent values.

Bibliography

References contained in recommendations (i.e. through "should" clauses)

The following documents are referred to in the text in such a way that some or all of their content, although not requirements strictly to be followed, constitutes highly recommended choices or course of action of this document. Subject to national regulation and/or any relevant contractual provisions, alternative standards could be used/adopted where technically justified. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1998 (all parts), *Design of structures for earthquake resistance*

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

Other references

The following documents are those not included in the above categories but are cited informatively in the document, for example in notes.

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

EN 10025 (all parts), *Hot rolled products of structural steels*

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

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

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

EN 10210-2, *Hot finished steel structural hollow sections - Part 2: Tolerances, dimensions and sectional properties*

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

EN 10219-2, *Cold formed welded steel structural hollow sections - Part 2: Tolerances, dimensions and sectional properties*

EN ISO 643, *Steels - Micrographic determination of the apparent grain size (ISO 643)*

EN ISO 6892-1, *Metallic materials - Tensile testing - Part 1: Method of test at room temperature (ISO 6892-1)*