



BSI Standards Publication

Eurocode 3: Design of steel structures

Part 1-9: Fatigue

National foreword

This British Standard is the UK implementation of EN 1993-1-9:2025. It supersedes BS EN 1993-1-9:2005, which will be withdrawn on 30 March 2028.

The UK participation in its preparation was entrusted to Technical Committee CB/203, Design & execution of steel structures, and Technical Committee B/525/10, Bridges.

A list of organizations represented on these committees can be obtained on request to their committee managers.

BSI, as a member of CEN, is obliged to publish EN 1993-1-9:2025 as a British Standard. However, attention is drawn to the fact that during the development of this European Standard, the UK committees voted against its approval. The UK committees submitted a negative vote due to their following concerns:

- It is the opinion of the UK committees that the revised presentation of the fatigue resistance curves between BS EN 1993-1-9:2005 and this standard could cause designers to neglect high cycle fatigue. In this standard, dashed lines are used to illustrate stress ranges below the constant amplitude fatigue limit $\Delta\sigma_D$ to emphasize that users only need to consider that portion of the curve for cases with variable amplitude loading when at least one stress range exceeds $\Delta\sigma_D$. BS EN 1993-1-9:2005 emphasized that users could only neglect stress ranges below $\Delta\sigma_D$ if they had constant amplitude loading or all stress ranges within variable amplitude loading were below $\Delta\sigma_D$. The UK committees advise users that in civil and building engineering structures in the UK, the incidence of constant amplitude loading is extremely rare. The UK committees believe this standard's use of dashed lines in this way has the potential to be unclear, as their opinion is that this is not consistent with the illustration of fatigue resistance curves in other design standards for metal structures, including BS EN 1999-1-3:2023.
- The UK committees note that there are numerous differences in the wording of term definitions in this standard compared to corresponding terms in BS EN 1999-1-3:2023.
- The geometric stress concentration effect resulting from joints between structural members where there is a lack of axial continuity through the joint is not addressed in the basic conditions requiring nominal stress to be modified by the stress concentration factor. It is the opinion of the UK committees that this is a fundamental fatigue design issue and requires proper consideration by designers.
- It is the opinion of the UK committees that the stated weld quality requirements (see Subclause 8.2 and Tables 10.1 to 10.13) are inadequate for some of the higher detail weld categories for safe life design.

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

The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2019. This document forms part of the second generation of EN Eurocodes.

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

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

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

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

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

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Amendments/corrigenda issued since publication

Date	Text affected
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English Version

Eurocode 3: Design of steel structures - Part 1-9: Fatigue

Eurocode 3: Calcul des structures en acier - Partie 1-9:
Fatigue

Eurocode 3: Bemessung und Konstruktion von
Stahlbauten - Teil 1-9: Ermüdung

This European Standard was approved by CEN on 29 December 2024.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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European foreword

This document (EN 1993-1-9:2025) 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 European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2027, and conflicting national standards shall be withdrawn at the latest by March 2028.

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

This document supersedes EN 1993-1-9:2005 and EN 1993-1-9:2005/AC:2009.

EN 1993-1-9:2025 includes the following significant technical changes with respect to EN 1993-1-9:2005 and EN 1993-1-9:2005/AC:2009:

- reorganization to achieve improvements in clarity and to accommodate to the new structure of all Eurocodes;
- alignment of terms with EN 1990:2002, extension of definitions, introduction of distinction between concepts and methods;
- adaptation of partial factors to three consequence classes from EN 1990:2002;
- elimination of misinterpretations in calculation of nominal stresses, in particular for welds; inclusion of rules on calculation of nominal stresses in bolts and rods; inclusion of guidance on the calculation of nominal stresses in preloaded bolts and rods subject to tension; inclusion of stress concentration factors k_t ;
- elimination of gaps for calculation of hot spot stresses, strongly linked with the development of prEN 1993-1-14:2022;
- inclusion of method for calculation of effective notch stresses, also linked with the development of prEN 1993-1-14:2022;
- inclusion of sets of fatigue resistance curves for normal stresses, for hot spot stresses and for effective notch stresses;
- update and extension or inclusion of detail category tables for all stress calculation methods;
- inclusion of recommendations for welded joints subjected to High Frequency Mechanical Impact (HFMI) treatment for nominal stress method.

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.

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

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

0 Introduction

0.1 Introduction to the Eurocodes

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

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

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 (all parts)

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 design.

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

EN 1993 is subdivided in various parts:

- EN 1993-1, *Design of steel structures — Part 1: General rules and rules for buildings*;
- EN 1993-2, *Design of steel structures — Part 2: Bridges*;
- EN 1993-3, *Design of steel structures — Part 3: Towers, masts and chimneys*;
- EN 1993-4, *Design of steel structures — Part 4: Silos and tanks*;
- EN 1993-5, *Design of steel structures — Part 5: Piling*;
- EN 1993-6, *Design of steel structures — Part 6: Crane supporting structures*;

- EN 1993-7,¹ *Design of steel structures — Part 7: Sandwich panels*.

EN 1993-1 in itself does not exist as a physical document, but as a document series that 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 are covered in EN 1993-1-1.
- EN 1993-1-4, *Design of steel structures — Part 1-4: Stainless steel structures*;
- EN 1993-1-5, *Design of steel structures — Part 1-5: Plated structural elements*;
- EN 1993-1-6, *Design of steel structures — Part 1-6: Strength and stability of shell structures*;
- EN 1993-1-7, *Design of steel structures — Part 1-7: Plate assemblies with elements under transverse loads*;
- EN 1993-1-8, *Design of steel structures — Part 1-8: Joints*;
- EN 1993-1-9, *Design of steel structures — Part 1-9: Fatigue*;
- EN 1993-1-10, *Design of steel structures — Part 1-10: Material toughness and through-thickness properties*;
- EN 1993-1-11, *Design of steel structures — Part 1-11: Tension components*;
- EN 1993-1-12, *Design of steel structures — Part 1-12: Additional rules for steel grades up to S960*;
- EN 1993-1-13, *Design of steel structures — Part 1-13: Beams with large web openings*;
- EN 1993-1-14, *Design of steel structures — Part 1-14: Design assisted by finite element analysis*.

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

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

0.3 Introduction to EN 1993-1-9

EN 1993-1-9 gives specific design rules for verification of the fatigue design situation of steel structures. It is intended to be used with EN 1990, EN 1991 and EN 1993-1. Matters that are already covered in those documents are not repeated. The focus in EN 1993-1-9 is on design rules that supplement, modify or supersede the equivalent provisions given in EN 1993-1.

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.

¹ Under preparation. Stage at the time of publication: prEN 1993-7.

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 1993-1-9

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

The national standard implementing EN 1993-1-9 can have a National Annex containing all national choices to be used for the design of steel structures to be constructed in the relevant country.

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

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

National choice is allowed in EN 1993-1-9 through notes to the following clauses:

4(6)	5(4)	5(6)	6.1(3)
6.2(3)	7.1(5)	8.2(1) – 2 choices	8.3.2(1)
9.1(1)	B.2(3)	B.2(4)	C.2(6)
F.2(2)	F.2(5)	F.3.2(1)	F.4.2.1(3)

National choice is allowed in EN 1993-1-9 on the application of the following Informative Annexes:

Annex D	Annex E	Annex F	Annex G
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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 1993-1-9

(1) EN 1993-1-9 gives design methods for the verification of the fatigue design situation of steel structures.

NOTE Steel structures consist of members and their joints. Each member and joint can be represented as a constructional detail or as several of the latter.

(2) Design methods other than the stress-based methods, such as the notch strain method or fracture mechanics methods, are not covered by EN 1993-1-9.

(3) EN 1993-1-9 only applies to structures made of all grades of structural steels and products within the scope of EN 1993-1 (all parts), in accordance with the provisions noted in the detail category tables or annexes.

(4) EN 1993-1-9 only applies to structures where execution conforms to EN 1090-2.

NOTE Supplementary execution requirements are indicated in the detail category tables.

(5) EN 1993-1-9 applies to structures operating under normal atmospheric conditions and with sufficient corrosion protection and regular maintenance. The effect of seawater corrosion is not covered.

(6) EN 1993-1-9 applies to structures with hot dip galvanizing in accordance with the provisions noted in the detail category tables or annexes.

(7) Microstructural damage from high temperature ($> 150^{\circ}\text{C}$) that occurs during the design service life is not covered.

(8) EN 1993-1-9 gives guidance of how to consider post-fabrication treatments that are intended to improve the fatigue resistance of constructional details.

1.2 Assumptions

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

(2) The design methods given in EN 1993-1-9 are applicable if:

- the execution quality is as specified in EN 1090-2, and
- the construction materials and products used are as specified in the relevant parts of EN 1993 (all parts), or in the relevant material and product specifications.

(3) The design methods of EN 1993-1-9 are generally derived from fatigue tests on constructional details with large scale specimens that include effects of geometrical and structural imperfections from material production and execution (e.g. the effects of tolerances and residual stresses from welding).

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

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

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

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, terms and definitions given in EN 1990, EN 1991 (all parts), EN 1993-1-1, EN 1993-1-5, EN 1993-1-8 and the following apply.

3.1.1 General

3.1.1.1

fatigue

gradually progressive, localized damaging process of a constructional detail within a structure subject to fatigue action (see 3.1.2.1) that can culminate in failure caused by crack initiation, propagation and fracture

Note 1 to entry: The type of failure depends on the definition of fatigue resistance, see 3.1.4.1.

3.1.1.2

design service life

reference period of time that depends on the type of structure for which its constructional details are required to perform safely with an appropriate level of reliability that failure by fatigue cracking will not occur

Note 1 to entry: EN 1990 gives provisions on design service life.

3.1.1.3

safe life concept

design concept in which an appropriate level of reliability for the fatigue design situation is obtained without the need for regular in-service inspection or monitoring for fatigue during the design service life

3.1.1.4

damage tolerant concept

design concept in which an appropriate level of reliability for the fatigue design situation is obtained by implementing prescribed inspection and maintenance for detecting and mitigating fatigue during the design service life

3.1.1.5**constructional detail**

part of a member or joint defined for fatigue purposes by the geometrical form and arrangement of the steel elements, the method of connection between them, the mode and direction of the applied cyclic stresses and the execution and inspection requirements

3.1.1.6**structural hollow section joint**

joint consisting of structural circular hollow sections (CHS) or structural rectangular hollow sections (RHS), or their combination as used in uniplanar or multi-planar trusses or girders

Note 1 to entry: Examples are T-, Y-, X-, K-, XX-, and KK-joints (see EN 1993-1-8).

3.1.1.7**rod**

circular solid threaded member made of structural steel including stainless steel

3.1.1.8**stress raising effect**

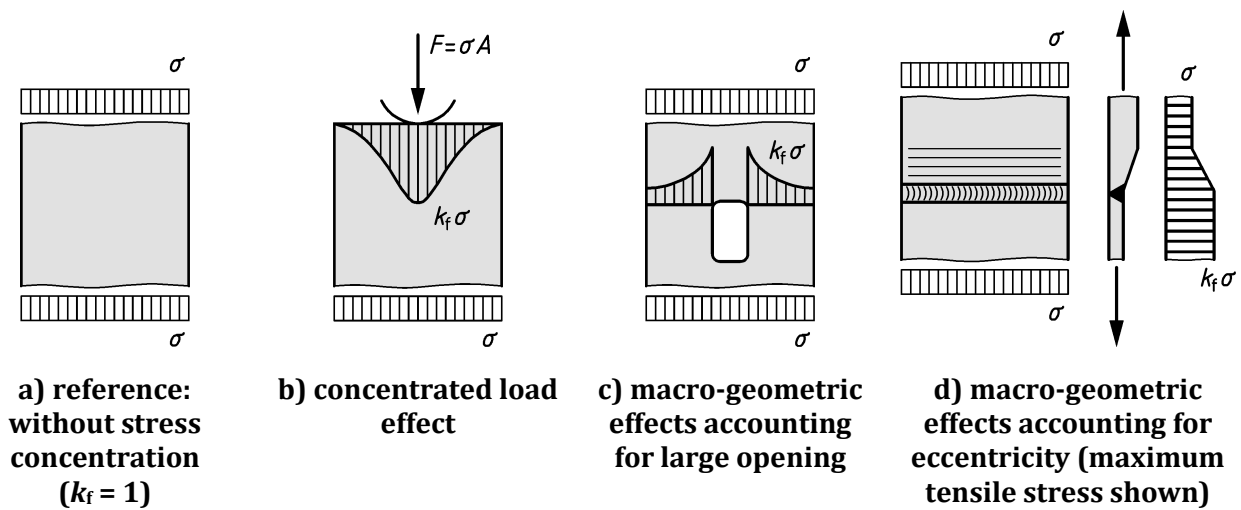
local increase in stress within a constructional detail caused by discontinuity in loading and/or geometry and/or material

3.1.1.9**stress concentration**

computable part of stress raising effect, expressed by the stress concentration factor k_f

Note 1 to entry: Figure 3.1 shows examples. Stress concentration factors are usually only available in the literature for concentrated load effects and geometric effects. Other k_f factors can be computed using finite element analysis, see EN 1993-1-14.

Note 2 to entry: The application of the stress concentration factor is indicated in the detail category tables by reference to the use of modified nominal stress.

**Key**

- σ nominal stress, see 3.1.1.17
- k_f stress concentration factor
- A cross-sectional area
- F concentrated load

Figure 3.1 — Examples of stress concentration factor k_f **3.1.1.10****concentrated load effect**

stress raising effect arising from discontinuity in loading e.g. caused by single loads, usually not taken into account in the detail category tables

Note 1 to entry: Figure 3.1b) shows an example.

3.1.1.11**macro-geometric effect**

stress raising effect arising from discontinuity in gross shape of a member, usually not taken into account in the detail category tables

Note 1 to entry: Examples are hard points caused by loss of cross sectional continuity in a joint (see Table 10.6, Detail 2), apertures, re-entrant corners, large openings as in Figure 3.1c), shear lag, curved members, secondary bending caused by eccentricities as in Figure 3.1d) and misalignments beyond the limits accounted for by the detail category tables.

3.1.1.12**misalignment**

unintended offset (linear misalignment) or out-of-straightness (angular misalignment) of the centrelines of adjacent connected elements within permitted limits for imperfections of the quality requirements

3.1.1.13**eccentricity**

intended offset (linear misalignment) of the centrelines of adjacent connected elements according to the design geometry

3.1.1.14**joint-geometric effect**

stress raising effect arising from discontinuity in local cross-section of a member caused by attachments or connected members

Note 1 to entry: Examples are shell bending stresses in addition to membrane stresses in plates caused by one-sided attachment, as in Figure 3.2c).

Note 2 to entry: Joint-geometric effects have already been taken into account in the detail categories based on nominal stresses, see Clause 10, but not in the detail categories based on hot spot or effective notch stresses, see Annexes B and C.

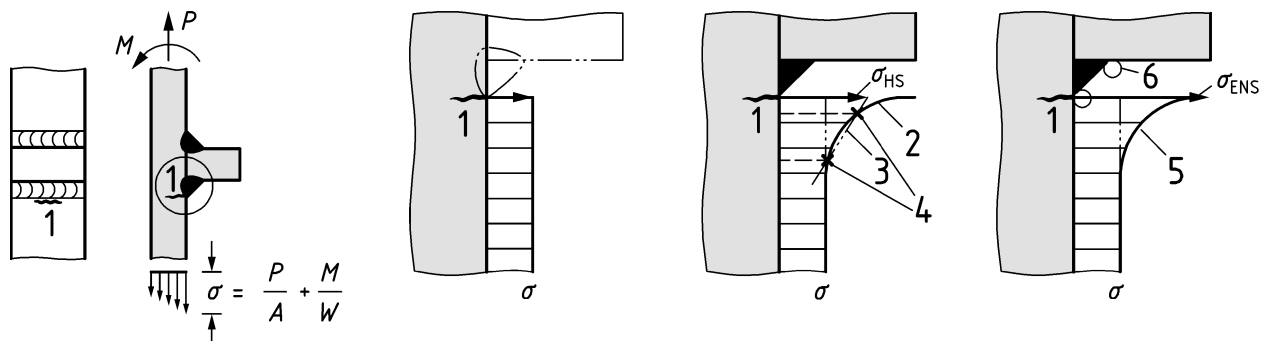
3.1.1.15**notch-geometric effect**

stress raising effect arising from discontinuity in local geometry of a member at a microscopic scale caused by notch geometry (notch radius)

Note 1 to entry: Examples for non-welded member are scratches, corrosion pits, rolling defects and manufacturing induced cracks. Examples for welded connections are weld profile shape, weld toes, weld roots, lack of fusion, slag inclusion, lack of penetration, cold laps and porosity, see Figure 3.2d).

3.1.1.16**material effect**

stress raising effect arising from discontinuity in material properties, such as regions with different yield strengths in the heat affected zone of welds, that are accounted for within the detail category tables

**a) transverse weld toe****b) nominal stress distribution****c) geometric stress distribution****d) effective notch stress distribution****Key**

- 1 potential fatigue crack location
- 2 true stress distribution on surface accounting for weld with sharply edged weld toes
- 3 linear stress extrapolation
- 4 stress calculation points at specified distances from weld toe
- 5 true stress distribution on surface accounting for weld with rounded off weld toes
- 6 round off radius for weld toe
- σ nominal stress at potential crack location (here: weld toe)
- σ_{HS} hot spot stress at potential crack location (see 3.1.1.20)

σ_{ENS} effective notch stress at potential crack location (see 3.1.1.22)

Figure 3.2 — Examples showing nominal, hot spot and effective notch stresses at a potential fatigue crack location at a weld toe

3.1.1.17

nominal stress

σ or τ

elastic stress in a constructional detail adjacent to a potential crack location, disregarding any stress raising effect

Note 1 to entry: Figure 3.2 b) shows an example of nominal stress distribution.

Note 2 to entry: The nominal stress as specified in EN 1993-1-9 can be a normal stress, a shear stress, a principal stress or an equivalent stress. The nominal stress is used when fatigue verification is performed using the detail category data in Clause 10.

Note 3 to entry: The joint-geometric (see 3.1.1.14), the notch-geometric (see 3.1.1.15) and the material effects (see 3.1.1.16) are accounted for by the nominal stress-based detail categories. See 3.1.1.18 if macro-geometric and/or concentrated load effects exist.

Note 4 to entry: For beam-like components with uniform loading, the nominal stress can be calculated by beam theory.

3.1.1.18

modified nominal stress

nominal stress multiplied by an appropriate stress concentration factor k_f to allow for geometric and/or concentrated load effects

Note 1 to entry: Figures 3.1b) to d) show examples.

3.1.1.19

geometric stress

structural stress

elastic stress within a welded constructional detail accounting for joint-geometric effects (and macro-geometric and concentrated load effects if applicable) and neglecting the notch-geometric and material effects

Note 1 to entry: Figure 3.2c) shows an example. The notch-geometric (see 3.1.1.15) and the material effects (see 3.1.1.16) are accounted for in Table B.1.

3.1.1.20

hot spot stress

σ_{HS}

stress at the weld toe of the considered constructional detail derived from the geometric stress (see 3.1.1.19) through stress extrapolation

Note 1 to entry: See EN 1993-1-14 for determination of hot spot stress.

3.1.1.21

notch stress

elastic stress in a constructional detail taking into account all stress concentrations

3.1.1.22**effective notch stress** σ_{ENS}

peak value of notch stress at potential crack location modelled with a specified effective notch radius

Note 1 to entry: Figure 3.2d) shows an example of effective notch stress distribution.

Note 2 to entry: See EN 1993-1-14 for determination of effective notch stress.

3.1.1.23**residual stresses**

permanent stresses in a member or structure in the absence of any external action

Note 1 to entry: Residual stresses can arise from rolling, cutting and forming processes, plastic deformation, thermal treatment, weld shrinkage or lack of fit between members. As external action is absent, the residual stresses locked in a member are self-balancing.

3.1.1.24**inspection**

examination for conformity by measuring, observing, or testing relevant characteristics

3.1.2 Fatigue actions**3.1.2.1****fatigue action**

action on a structure arising from loading events for which the number of reoccurrences cannot be neglected in structural design as the action effect within constructional details can cause fatigue

Note 1 to entry: Fatigue Load Model is also used for this term, see EN 1991-2.

Note 2 to entry: Examples of fatigue actions are:

- axle loads and spacings for different types of road vehicles and railway trains,
- transverse forces due to alternate vortex-shedding on masts, towers and chimneys,
- wheel loads of cranes on crane runway beams.

Note 3 to entry: The relevant parts of EN 1991 give representative values of some commonly applied fatigue actions.

3.1.2.2**loading event****load cycle**

period of time with a defined variation in magnitude and/or point of application of the fatigue action that can be considered to reoccur a number of times

Note 1 to entry: Examples of loading events are:

- sequence summarising the approach, passage and departure of road vehicles and railway trains,
- shedding of a pair of alternating vortices in case of masts, towers, chimneys,
- sequence of crane operations commencing when a payload is hoisted and ending when the crane is ready to hoist the next payload in case of crane runway beams.

3.1.2.3

loading history

presentation of the expected fatigue action on a structure (considering prediction inaccuracy) during its design service life by arranging the loading events in chronological sequence

3.1.2.4

action spectrum

evaluation of the loading history of a structure presenting the different levels of fatigue action with the associated relative frequency (number of load cycles) in descending order by neglecting sequence effects

Note 1 to entry: The fatigue action can be described by ordinary spectra (relationship of different action levels Q_i and associated numbers of load cycles N_i) or by cumulative spectra (also called sum-spectra; relationship of different action levels Q_i and associated number of load cycles $\sum N_i$ for which this action level is reached or exceeded).

Note 2 to entry: Figure 3.3 shows examples of action spectra that are commonly used:

- discrete action spectrum of different action levels Q_i , Figure 3.3a)
- continuous action spectrum characterized by $Q_{\max}$, $N_{\max}$ and a standardized spectrum shape, Figure 3.3b)
- equivalent constant action spectrum characterized by Q_e and $N_{\max}$, Figure 3.3c)
- equivalent constant action spectrum characterized by $Q_{e,2}$ and 2×10^6 load cycles representing a simplified fatigue load model in the relevant parts of EN 1991, Figure 3.3d).

Note 3 to entry: EN 1990 contains general provisions for structures for which the relevant part of EN 1991 does not provide loading spectra.

Note 4 to entry: The equivalent constant loading spectra characterized by $Q_{e,2}$ and 2×10^6 load cycles replace real discrete or continuous load spectra.

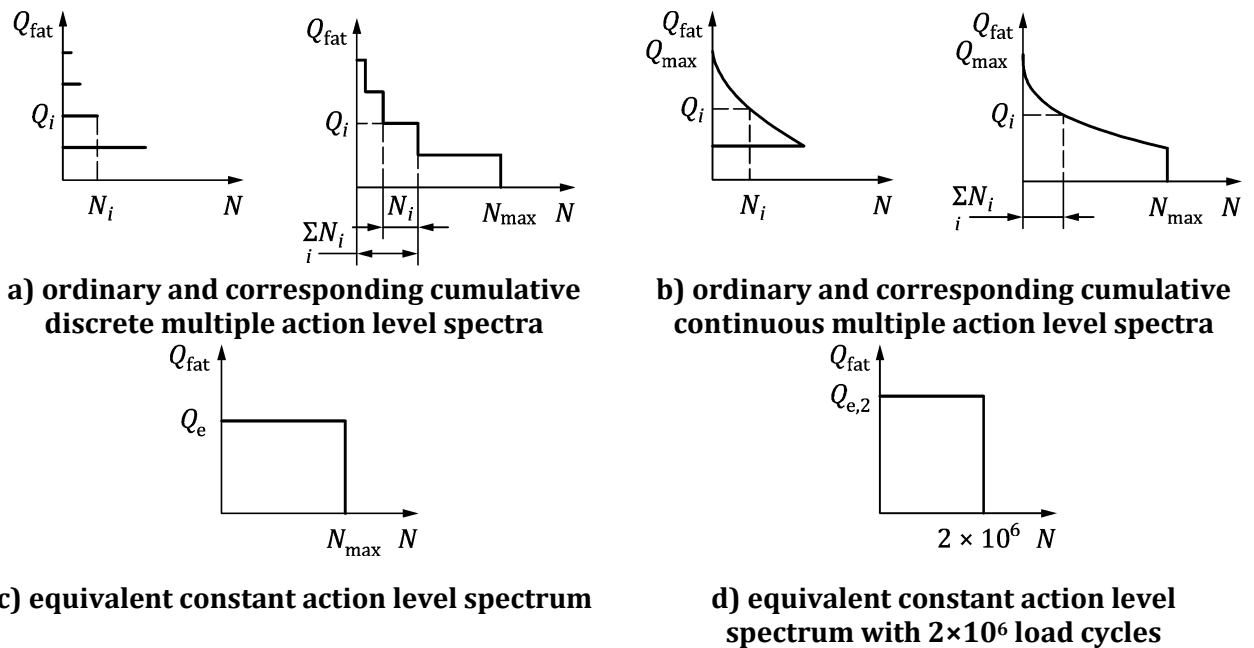


Figure 3.3 — Commonly used representations of action spectra

3.1.3 Fatigue action effect

3.1.3.1

fatigue action effect

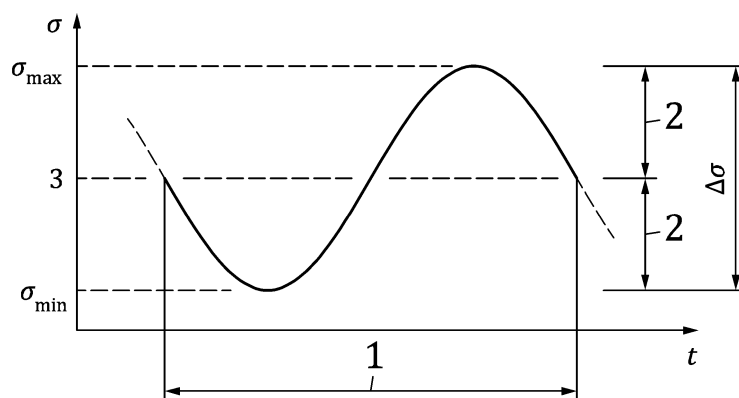
resulting stress effect from the application of the fatigue action on a constructional detail that is composed of stress cycles

3.1.3.2

stress cycle

time interval with a defined stress variation between a maximum and minimum stress starting and ending at the same stress level

Note 1 to entry: Stress cycle is denoted '1' in Figure 3.4.



Key

$\sigma_{\min}$	minimum stress
$\sigma_{\max}$	maximum stress
$\Delta\sigma$	stress range
t	time
1	stress cycle
2	stress amplitude
3	mean stress

Figure 3.4 — Stress cycle parameters (also applicable for shear stress cycles)

3.1.3.3

stress history

presentation of the expected fatigue action effect in chronological sequence

3.1.3.4

stress range

difference between maximum and minimum stress of a stress cycle

Note 1 to entry: Stress range is shown in Figure 3.4.

3.1.3.5

stress ratio

R

ratio of minimum and maximum stress of a particular stress cycle, with stresses calculated including the static load effects from EN 1990:2023, 8.3.4.5

Note 1 to entry: The influence of stress ratio typically exists for non-welded constructional details with thermal stress relief or post-weld treatment as specified in Annex F.

3.1.3.6

thermal stress relief

reduction in residual stress as a result of thermal treatment (e.g. post weld heat treatment)

3.1.3.7

stress amplitude

half of stress range of a particular stress cycle

Note 1 to entry: Stress amplitude is denoted ' σ ' in Figure 3.4.

3.1.3.8

constant amplitude fatigue action effect

fatigue action effect where all stress cycles have the same stress range

3.1.3.9

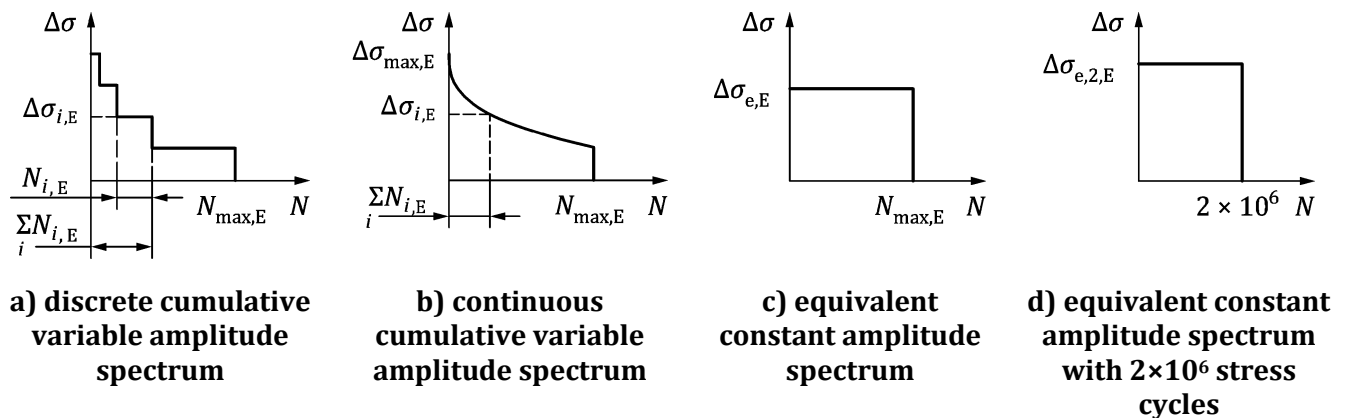
variable amplitude fatigue action effect

fatigue action effect where the stress ranges vary between stress cycles

3.1.3.10

stress-range spectrum

evaluation of expected stress history presenting the different stress ranges and the associated relative frequency (number of stress cycles) commonly presented in descending order neglecting sequence effects through cycle counting methods, such as the rainflow and reservoir methods



Key

$\Delta\sigma_{i,E}$	stress range level
$\Delta\sigma_{\max,E}$	maximum stress range
$N_{i,E}$	number of stress cycles at level $\Delta\sigma_{i,E}$
$\Sigma N_{i,E}$	number of stress cycles for which $\Delta\sigma_{i,E}$ is reached or exceeded
$N_{\max,E}$	total number of stress cycles
$\Delta\sigma_{e,E}$	damage equivalent stress range
$\Delta\sigma_{e,2,E}$	damage equivalent stress range with 2×10^6 stress cycles

Figure 3.5 — Commonly used representations of stress-range spectra

Note 1 to entry: As for action spectra in Figure 3.3, the fatigue action effect can also be described by ordinary spectra (relationship of applied stress ranges $\Delta\sigma_{i,E}$ or $\Delta\tau_{i,E}$ and associated numbers of stress cycles $N_{i,E}$) or by cumulative spectra (also called sum-spectra; relationship of applied stress ranges $\Delta\sigma_{i,E}$ or $\Delta\tau_{i,E}$ and associated number of stress cycles $\Sigma N_{i,E}$ for which this stress range is reached or exceeded). The following types of stress-range spectra are commonly used:

- discrete spectrum of different stress range levels $\Delta\sigma_{i,E}$ or $\Delta\tau_{i,E}$ and associated numbers of stress cycles $N_{i,E}$, see Figure 3.5a),

- continuous spectrum characterized by maximum stress range $\Delta\sigma_{\max,E}$ or $\Delta\tau_{\max,E}$, total number of stress cycles $N_{\max,E}$ and a standardized spectrum shape, see Figure 3.5b),
- equivalent constant stress range spectrum with $\Delta\sigma_{e,E}$ or $\Delta\tau_{e,E}$ and total number of stress cycles $N_{\max,E}$, see Figure 3.5c),
- equivalent constant stress range spectrum with $\Delta\sigma_{e,2,E}$ or $\Delta\tau_{e,2,E}$ and 2×10^6 stress cycles, see Figure 3.5d).

Note 2 to entry: The equivalent constant stress range spectrum with $\Delta\sigma_{e,2,E}$ and 2×10^6 stress cycles is the effect of a simplified fatigue load model in the relevant parts of EN 1991 representing an equivalent loading spectrum with $Q_{e,2}$ and 2×10^6 load cycles (see 3.1.2.4). The fatigue load model causes a stress range that is adjusted by λ -values to obtain $\Delta\sigma_{e,2,E}$. The λ -values account for the influence of the real loading spectrum and are dependent on the type of structure (bridge, mast, crane runway etc.) and the kind of stress.

Note 3 to entry: For some applications, a load cycle can cause multiple stress cycles for the considered constructional detail. The number of stress cycles (N_E) rather than the number of load cycles (N) is always decisive for the fatigue design situation.

3.1.3.11

cycle counting

process of transforming a stress history into a stress range spectrum

Note 1 to entry: Cycle counting methods can be the rainflow method or the reservoir method, see 3.1.3.12 and 3.1.3.13.

3.1.3.12

rainflow method

particular cycle counting method of producing a stress-range spectrum from a given stress history

Note 1 to entry: For the mathematical determination see EN 1990:2023, Annex F.

3.1.3.13

reservoir method

particular cycle counting method of producing a stress-range spectrum from a given stress history

Note 1 to entry: For the mathematical determination see EN 1990:2023, Annex F.

3.1.4 Fatigue resistance

3.1.4.1

fatigue resistance

capacity of a constructional detail to withstand fatigue actions without fatigue failure, with an appropriate level of reliability

Note 1 to entry: The term 'fatigue resistance' covers both resistance in terms of stress range and resistance in terms of endurance. The term 'fatigue strength' can be used to cover resistance in terms of stress range only.

3.1.4.2

fatigue life

number of stress cycles that a constructional detail can withstand without fatigue failure (crack initiation)

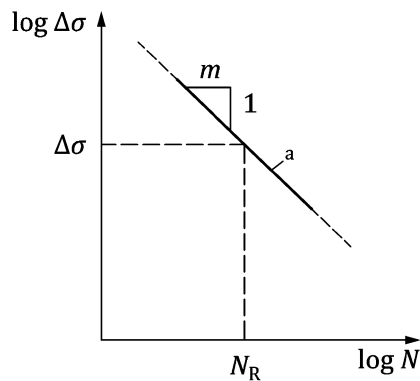
Note 1 to entry: The fatigue life depends on the stress range spectrum. For a particular structure, the fatigue life can alternatively be expressed as a period of time.

3.1.4.3

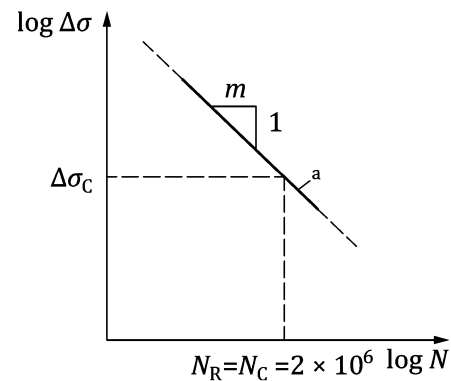
fatigue resistance curve

calculation model for the fatigue resistance of a constructional detail that establishes a quantitative relationship between stress range $\Delta\sigma$ and the corresponding endurance N_R

Note 1 to entry: Figure 3.6a) shows a fatigue resistance curve.



a) Endurance N_R of any stress range $\Delta\sigma$



b) Reference value at 2×10^6 stress cycles

Key

- a fatigue resistance curve
- m slope parameter of fatigue resistance curve
- $\Delta\sigma$ stress range
- N_R endurance associated with $\Delta\sigma$
- $\Delta\sigma_C$ reference value at 2×10^6 stress cycles

Figure 3.6 — Definition of endurance and reference value of fatigue resistance curve (also applicable for shear stress ranges)

Note 2 to entry: The characteristic fatigue resistance curves given in EN 1993-1-9 are lower bound values based on the evaluation of fatigue tests with large scale test specimens.

Note 3 to entry: The characteristic fatigue resistance curves are also known as S-N curves or Wöhler curves.

Note 4 to entry: For simplification, the characteristic fatigue resistance curves of the constructional details in this document are attributed to detail categories.

3.1.4.4

endurance

N_R

fatigue life of a constructional detail under a stress range $\Delta\sigma$ or $\Delta\tau$ that is obtained from the corresponding fatigue resistance curve

Note 1 to entry: Endurance is shown in Figure 3.6a).

3.1.4.5

characteristic reference value of fatigue resistance

$\Delta\sigma_c, \Delta\tau_c$

mechanical property of a constructional detail expressing its characteristic fatigue resistance in terms of a stress range $\Delta\sigma_c$ or $\Delta\tau_c$ for an endurance of $N_R = N_C = 2 \times 10^6$ stress cycles

Note 1 to entry: Characteristic reference value of fatigue resistance is shown in Figure 3.6b).

Note 2 to entry: 'Reference value of fatigue resistance' is also commonly referred to as 'fatigue strength'.

3.1.4.6

detail category

DC

characteristic reference value $\Delta\sigma_c$ or $\Delta\tau_c$ of fatigue resistance in N/mm^2 identifying a particular fatigue resistance curve, together with the relevant slope parameter specified in the detail category tables

Note 1 to entry: The detail category attributed to a particular constructional detail can generally be obtained from the first column of the detail category tables depending on the chosen design stress method (see 6.1).

3.1.4.7

slope parameter

m

parameter of the fatigue resistance curve expressing the intensity of fatigue damage

Note 1 to entry: Slope parameter is shown in Figure 3.6.

Note 2 to entry: In mathematics, the slope parameter is identical with the negative inverse slope of the fatigue resistance curve.

Note 3 to entry: The fatigue resistance curve can have different slope parameters. The first slope parameter is denoted as m_1 and the second as m_2 .

3.1.4.8

constant amplitude fatigue limit

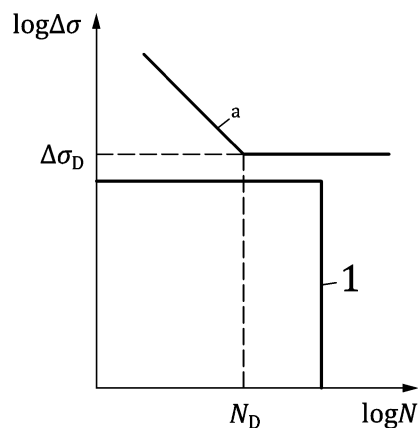
CAFL

$\Delta\sigma_b, \Delta\tau_b$

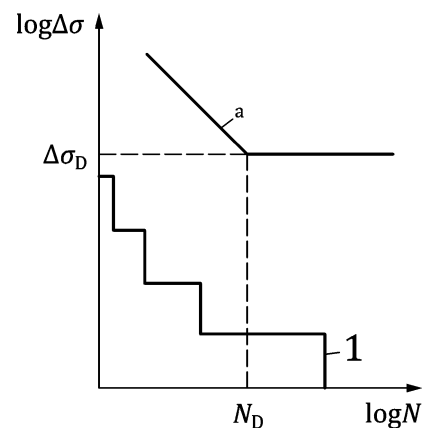
characteristic maximum stress range, for constant or variable stress range spectra, for which a constructional detail can withstand an infinite number of stress cycles without fatigue damage

Note 1 to entry: Figure 3.7 is a simplification. The verification with respect to the CAFL, that takes partial factors into account, is described in 9.3.

Note 2 to entry: The verification with respect to the CAFL for design situations with variable amplitude fatigue action effect is only possible where the real maximum stress range is known and stays below $\Delta\sigma_b$ or $\Delta\tau_b$, see Figure 3.7b). The fatigue load models in the relevant parts of EN 1991 do not allow the determination of the real maximum stress range. See details in 9.3.



a) constant amplitude fatigue action effect

b) variable amplitude fatigue action effect
with known maximum stress range**Key**

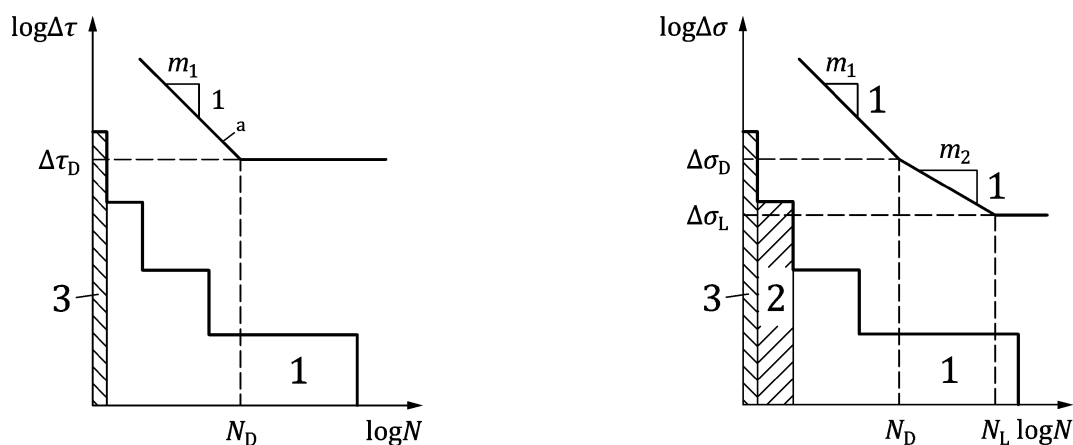
- 1 stress range spectrum not contributing to fatigue damage
- a fatigue resistance curve
- $\Delta\sigma_D$ CAFL
- N_D number of stress cycles linked with the CAFL

Figure 3.7 — Spectra with all stress ranges below CAFL (also applicable for shear stressing)**3.1.4.9****variable amplitude fatigue limit****VAFL** **$\Delta\sigma_L$**

characteristic maximum stress range, for variable amplitude stress range spectra, below which the stress ranges do not need to be considered in calculating the fatigue damage

Note 1 to entry: For constructional details subject to shear stress ranges, the value of the CAFL is the same as that of the VAFL. Thus, all stress ranges below $\Delta\tau_D$ are not considered in the fatigue damage calculation for constructional details with such fatigue resistance curves. Figure 3.8a) is a simplification neglecting partial factors.

Note 2 to entry: For constructional details with a fatigue resistance curve having slope parameters m_1 and m_2 , the stress ranges between $\Delta\sigma_D$ and $\Delta\sigma_L$ contribute to fatigue damage, if the stress range spectrum also comprises stress ranges above $\Delta\sigma_D$. Figure 3.8b) is a simplification neglecting partial factors.



a) Fatigue resistance curve with same CAFL and VAFL levels

b) Fatigue resistance curve with separate CAFL and VAFL levels

Key

- 1 stress ranges not contributing to fatigue damage
- 2 stress ranges contributing to fatigue damage with slope parameter m_2
- 3 stress ranges contributing to fatigue damage with slope parameter m_1
- a fatigue resistance curve
- $\Delta\sigma_D$ CAFL for details subject to normal stresses
- $\Delta\tau_D$ CAFL for details subject to shear stresses
- $\Delta\sigma_L$ VAFL for details subject to normal stresses and two-slope fatigue resistance curve
- N_D number of stress cycles linked with the CAFL
- N_L number of stress cycles linked with the VAFL

Figure 3.8 — Spectra with stress ranges above and below CAFL

3.1.4.10

manual welding

welding in which all operations are carried out manually (the electrode holder, gun, torch or blowpipe is manipulated by hand)

3.1.4.11

fully mechanized welding

welding in which all main operations (excluding the handling of the work piece) are performed automatically

Note 1 to entry: Manual adjustment of welding variables during welding is possible.

3.1.4.12

automatic welding

welding in which all operations are performed automatically

Note 1 to entry: Manual adjustment of welding variables during welding is not possible.

3.1.4.13**High Frequency Mechanical Impact (HFMI) treatment**

qualified continuous peening process carried out by traversing a hardened rounded tipped tool along a surface whilst it is subjected to high frequency hammer blows produced by machine

Note 1 to entry: Qualification involves application of a pre-approved procedure to a specific welded joint geometry, which is then subjected to fatigue testing.

Note 2 to entry: Investigation in [16] showed that the following HFMI technologies are comparable:

- HiFIT (High Frequency Impact Treatment)
- PIT (Pneumatic Impact Treatment)
- UIT (Ultrasonic Impact Treatment).

3.1.4.14**operator**

appropriately trained person who is able to operate the HFMI-device properly

3.1.4.15**device manufacturer**

company that manufactures the HFMI-device

3.1.5 Fatigue verification**3.1.5.1****fatigue damage**

D_i

fatigue damage due to a stress range $\Delta\sigma_{i,E}$ associated to $N_{i,E}$ stress cycles, expressed by the ratio of $N_{i,E}$ and the endurance, $N_{i,R}$, of this constructional detail under the same stress range ($D_i = N_{i,E} / N_{i,R}$)

3.1.5.2**accumulated fatigue damage**

D

sum of fatigue damages from all stress ranges in a spectrum

3.1.5.3**Miner's summation**

linear cumulative summation of the fatigue damage from all stress cycles accounted for in a stress-range spectrum, based on the Palmgren-Miner rule

3.2 Symbols

3.2.1 Latin upper-case letters

A	cross-sectional area
A_s	stress area of the bolt or rod
CAFL	Constant Amplitude Fatigue Limit
CHS	Circular Hollow Section
D	accumulated fatigue damage due to different stress ranges ($D = \sum D_i$)
D_i	fatigue damage due to a stress range $\Delta\sigma_{i,E}$ with the associated number of $N_{i,E}$ stress cycles ($D_i = N_{i,E} / N_{i,R}$)
EVM	Equivalent von Mises
F	concentrated load
F_B	force acting on the bolt or rod
F_C	reduction of the compressive force of the clamped components due to F_T
F_T	external tensile force applied to the preloaded bolted joint or joint with rod
FEM	Finite Element Method
FLM	Fatigue Load Model
HFMI	High Frequency Mechanical Impact
I	second moment of area
N	number of cycles
N_C	number of stress cycles associated with the characteristic reference value of fatigue resistance
N_D	number of stress cycles associated with the characteristic constant amplitude fatigue limit
NDT	Non Destructive Testing
NDP	Nationally Determined Parameter
N_i	number of load cycles of an applied fatigue action level Q_i
$N_{i,E}$	number of stress cycles of an applied stress range $\Delta\sigma_{i,E}$
$N_{i,R}$	number of stress cycles which can be resisted by a constructional detail under an applied stress range $\Delta\sigma_{i,E}$ until failure (endurance)
N_L	number of stress cycles associated with the variable amplitude fatigue limit
$N_{\max}$	total number of load cycles
$N_{\max,E}$	total number of stress cycles
N_R	endurance
N_{Rd}	design value of endurance
PS	principal stress
Q_{fat}	fatigue action
Q_e	equivalent action for $N_{\max}$ load cycles
$Q_{e,2}$	equivalent action for 2×10^6 load cycles

Q_i	action value for N_i load cycles
$Q_{\max}$	maximum action value
R	stress ratio ($R = \sigma_{\min}/\sigma_{\max}$)
RHS	Rectangular Hollow Section
$S(t)$	first moment of area
V	shear force in a cross section
VAFL	Variable Amplitude Fatigue Limit
V_B	shear force per shear plane acting on the bolt or rod
VM	Von Mises

3.2.2 Latin lower-case letters

aw	as-welded
k_1	magnification factor for nominal stress ranges to account for secondary bending moments in trusses
k_f	stress concentration factor
k_s	reduction factor for fatigue resistance (in terms of stress) to account for size effects
log	logarithm with base 10
m	slope parameter of a fatigue resistance curve
m_{aw}	slope parameter of fatigue resistance curve for as-welded state
m_{HFMI}	slope parameter of fatigue resistance curve for HFMI state
t	plate thickness

3.2.3 Greek upper-case letters

$\Delta\sigma_C, \Delta\tau_C$	characteristic reference value of fatigue resistance at $N_C = 2 \times 10^6$ stress cycles
$\Delta\sigma_{C,\text{HFMI}}$	characteristic reference value of the fatigue resistance at $N_C = 2 \times 10^6$ stress cycles for HFMI
$\Delta\sigma_{C,\text{red}}$	reduced characteristic reference value of the fatigue resistance
$\Delta\sigma_D, \Delta\tau_D$	characteristic constant amplitude fatigue limit at N_D stress cycles
$\Delta\sigma_E, \Delta\tau_E$	fatigue action effect (stress ranges)
$\Delta\sigma_{e,2,E}, \Delta\tau_{e,2,E}$	equivalent stress range applied 2×10^6 stress cycles
$\Delta\sigma_{e,E}, \Delta\tau_{e,E}$	equivalent stress range applied $N_{\max,E}$ stress cycles
$\Delta\sigma_{e,2,\text{HFMI},E}$	equivalent stress range for HFMI treated joints, i.e. accounting for λ_{HFMI}
$\Delta\sigma_{\text{eq},E}$	equivalent stress range for connections in webs of orthotropic decks
$\Delta\sigma_{i,E}, \Delta\tau_{i,E}$	stress range level applied $N_{i,E}$ stress cycles
$\Delta\sigma_L$	characteristic variable amplitude fatigue limit at N_L stress cycles
$\Delta\sigma_{\max,\text{Ed}}, \Delta\tau_{\max,\text{Ed}}$	correspond to $\max\Delta\sigma_{i,\text{Ed}}$ and $\max\Delta\tau_{i,\text{Ed}}$

$\Delta\sigma_s$	characteristic stress range at intersection of fatigue resistance curves for as-welded and HFMI state
ΣN_i	accumulated number of load cycles for which a fatigue action level Q_i is reached or exceeded
$\Sigma N_{i,E}$	accumulated number of stress cycles for which an applied stress range $\Delta\sigma_{i,E}$ or $\Delta\tau_{i,E}$ is reached or exceeded

3.2.4 Greek lower-case letters

γ_{Ff}	partial factor for applied stress ranges $\Delta\sigma_E$, $\Delta\tau_E$
γ_{Mf}	partial factor for fatigue resistance
λ_{HFMI}	supplementary damage equivalent factor to consider the mean stress effect in spectrum in case of HFMI treatment
λ_i	damage equivalent factors depending on, for example, the load situation and the structural characteristics
σ	nominal normal stress
σ_{ENS}	effective notch stress
σ_{HS}	hot spot stress
σ_{max}	maximum stress of a cycle, calculated considering all relevant effects in the fatigue design situation
σ_{min}	minimum stress of a cycle, calculated considering all relevant effects in the fatigue design situation
τ	nominal shear stress

4 Basis of fatigue design

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

NOTE EN 1991 (all parts) gives provisions on fatigue actions for particular types of structures such as bridges, masts, towers, chimneys and crane supporting structures. See definitions in 3.1.2.

(2) Steel structures designed according to this document shall be executed according to EN 1090-2.

(3) The methods for the verification of the fatigue design situation given in Clause 6 should follow the principle of verification by the partial factor method by comparing fatigue action effects and compatible fatigue resistances.

(4) In the case fatigue cracks are observed, they should be either monitored in a specific inspection regime or repaired with particular care to avoid introducing more severe stress raising effects.

NOTE The action to undertake depends on the consequence of failure, see Clause 5.

(5) Fatigue tests on specimens may be carried out to determine:

- the fatigue resistance for constructional details not included in this document,
- the fatigue life of prototypes of a serial production.

NOTE Prototype testing considering the design loading spectrum, in connection with a statistical evaluation of the test results according to EN 1990:2023, Annex D, can be used to determine the characteristic fatigue life of the tested component. The actual characteristic fatigue resistance ($\Delta\sigma_c$) of the component's constructional details remains unknown.

(6) The statistical evaluation of fatigue tests should be in accordance with EN 1990.

NOTE 1 NOTE 2 to 8.2(1) contains detailed information on evaluation of fatigue tests.

NOTE 2 The National Annex can give requirements for determining fatigue resistance from tests.

5 Fatigue design concepts

(1) The fatigue design situation should be verified using either:

- a) safe life concept or
- b) damage tolerant concept.

(2) The safe life concept should provide an appropriate level of reliability that the performance of a structure will not be impaired throughout its design service life without the need for regular in-service inspection or monitoring for fatigue cracks.

(3) The safe life concept should be applied in cases where local formation of cracks in one constructional detail could rapidly lead to failure of a structure or one of its parts.

(4) The damage tolerant concept should provide an appropriate level of reliability that the performance of a structure will not be impaired throughout its design service life, provided that readily inspectable details are used and prescribed inspection and maintenance, for detecting and preventing fatigue cracks, is implemented.

NOTE The National Annex can give provisions for inspection and maintenance. The inspection intervals and methods can be based on crack growth calculations, on experience, monitoring, or previous inspection results and can be a function of the consequence of failure. Maintenance can include component replacements at given intervals. It can further give provisions for changes in inspection intervals and methods in case of monitoring or after repairing detected cracks.

(5) Appropriate constructional details, materials and stress levels should be selected for the design concept to ensure an appropriate level of reliability in accordance with EN 1990, at least equal to the reliability required for ultimate limit state verification, is achieved for:

- a) safe-life concept
 - at the end of the design service life;
- b) damage tolerant concept
 - at the end of each in-service inspection interval, so that in the event of the formation of cracks at least one or all of the following safety mechanisms are ensured:
 - low propagation rates and easily detectable cracks prior to failure,
 - multiple load paths,
 - crack-arresting constructional details prevent progressive damage.

NOTE The verification of the fatigue design situation includes long-term uncertainties, related to the fatigue resistance and actions, such that the possibility for fatigue cracking cannot be completely excluded but only reduced to an acceptable likelihood of occurrence.

(6) For the purpose of verification of fatigue design situation using this document, an appropriate level of reliability should be achieved by adjustment of the partial factor for fatigue resistance, γ_{Mf} , taking into account the consequences of failure and the design concept used.

NOTE 1 The values of the partial factors γ_{Mf} are given in Table 5.1 (NDP) unless the National Annex gives different values.

NOTE 2 The partial factors in Table 5.1 (NDP) for low consequences satisfy the reliability requirement for class of consequences CC1 according to EN 1990, those for medium consequence satisfy CC2, and those for high consequence satisfy CC3.

NOTE 3 The partial factors in Table 5.1 (NDP) are based on the possibility to perform visual inspections. The values can be function of inspection intervals and methods.

Table 5.1 (NDP) — Recommended values of the partial factors for fatigue resistance γ_{Mf}

Design concept	Consequence of failure		
	Low consequence	Medium consequence	High consequence
Safe life	1,15	1,25	1,35
Damage tolerant	1,00	1,15	1,25

6 Fatigue design methods

6.1 Design stress methods

(1) All relevant stress raising effects shall be considered in the verification of the fatigue design situation independent of the chosen design stress method.

NOTE Design stress methods are the nominal stress method, hot spot-stress method and effective notch stress method.

(2) Where stress raising effects are not included within the fatigue action effect according to a given design stress method, the stress raising effects should be accounted for within the fatigue resistance.

NOTE The different kinds of stress raising effects are explained in 3.1.1.8.

(3) The requirements expressed in (1) and (2) may be assumed to be satisfied by the fatigue design situation verification according to Clause 9, where the fatigue action effects are based on nominal or modified nominal stresses according to Clause 7, and the fatigue resistances according to Clause 8 are used.

NOTE For constructional details treated by HFMI, Annex F gives guidelines for the determination of fatigue action effects and corresponding fatigue resistances, unless the National Annex specifies differently.

(4) For the determination of fatigue action effects and corresponding fatigue resistances according to the hot spot stress method, use the provisions of Annex B (normative).

(5) For the determination of fatigue action effects and corresponding fatigue resistances according to the effective notch stress method, use the provisions of Annex C (normative).

6.2 Verification methods

(1) The method of verification shall be based upon calculation models that are appropriate for the fatigue design situation.

(2) For the following fatigue design situations, the verification methods of Clause 9 should be used:

- situations when the fatigue action effect is described by an equivalent constant stress range spectrum, ($\Delta\sigma_{e,2,Ed}$ or $\Delta\tau_{e,2,Ed}$) with 2×10^6 stress cycles;
- situations when the fatigue action effect is described by a variable amplitude stress range spectrum, with known maximum fatigue action effects ($\Delta\sigma_{\max,Ed}$ or $\Delta\tau_{\max,Ed}$).

NOTE See 3.1.3.10 for stress range spectra. An equivalent constant stress range spectrum is usually based on a simplified fatigue load model of the relevant part of EN 1991 with appropriate λ_i -values, see Figure 3.5d).

(3) For fatigue design situations with any other kind of stress range spectrum, use the verification method of Annex A (normative).

NOTE 1 Examples are variable amplitude stress range spectra, where maximum stress ranges ($\Delta\sigma_{\max,Ed}$ or $\Delta\tau_{\max,Ed}$) are not known, see Figure 3.5a) and b).

NOTE 2 The National Annex can give information on the use of Annex A.

7 Fatigue action effect

7.1 Calculation of nominal stresses

(1) The nominal stresses from fatigue actions should be calculated using linear elastic analysis according to EN 1993-1-1.

NOTE EN 1993-1-1:2022 includes rules for:

- section properties of net area in 8.2.2.2,
- shear lag effects in 8.2.2.3,
- elastic stresses due to shear in 8.2.6(4),
- elastic stresses due to torsion in 8.2.7(3).

(2) For constructional details of steel members in composite structures, the nominal stresses should be calculated considering all effects caused by other materials in the fatigue design situation.

NOTE For steel concrete composite structures, concrete cracking under normal service conditions can affect the nominal stresses of the steel members. In these cases, actions such as the permanent actions, variable actions, shrinkage, or creep, can have an influence on the nominal stresses.

(3) Modified nominal stresses should be used for the verification where stress concentrations due to macro-geometric effects and/or concentrated load effects occur close to the potential crack location shown in the illustrations of Table 10.1 to Table 10.12 and where such effects are not included in the detail category of the considered detail according to the detail description of the tables.

(4) Class 4 cross sections may be treated as Class 3 cross sections for fatigue if the width to thickness ratios are less than the limiting proportions for Class 3 obtained from EN 1993-1-1 when ε is multiplied by $\sqrt{f_{y,k} \gamma_{M0} / \sigma_{\text{com},f}}$, where $\sigma_{\text{com},f}$ is the maximum design compressive stress due to the combination of fatigue actions with other actions, as given in EN 1990:2023, 8.3.4.5.

(5) The nominal stresses in cross sections classified as Class 4 for fatigue should be divided by the reduction factors for buckling as for the reduced stress method of EN 1993-1-5, where the plate slenderness may be determined with the maximum design compressive stress in the considered cross-sectional part determined using the effective area of the section caused by all simultaneous action effects $\sigma_{\text{com},f}$.

NOTE The National Annex can give limitations for class 4 sections subject to fatigue action effects.

7.2 Relevant nominal stresses

(1) All nominal stresses, relevant for the constructional detail, shall be accounted for in the verification of the fatigue design situation.

(2) For each relevant nominal stress, the corresponding detail category should be determined from Table 10.1 to Table 10.12 accounting for the constructional detail, the type of stress (σ or τ) and the stress component. The supplementary requirements of the detail category on the stress calculation should be considered in addition to the provisions of 7.1.

NOTE For example, the detail category can require the stress calculation at a particular location of the constructional detail or can forbid simplifications that are allowed in EN 1993-1-1.

(3) For unwelded constructional details and for welded constructional details with weld toe failure, the relevant nominal stresses should be:

- nominal normal stresses σ in the parent metal, and/or
- nominal shear stresses τ in the parent metal.

(4) For weld root failure of load-carrying partial penetration butt welds or fillet welds, the forces transmitted by a unit length of weld should be resolved into components transverse and parallel to the longitudinal axis of the weld.

(5) The relevant nominal stresses in the weld should be taken as, see Figure 7.1:

- normal stresses σ_{wf} transverse to the longitudinal axis of the weld, and
- shear stresses τ_{wf} parallel to the longitudinal axis of the weld.

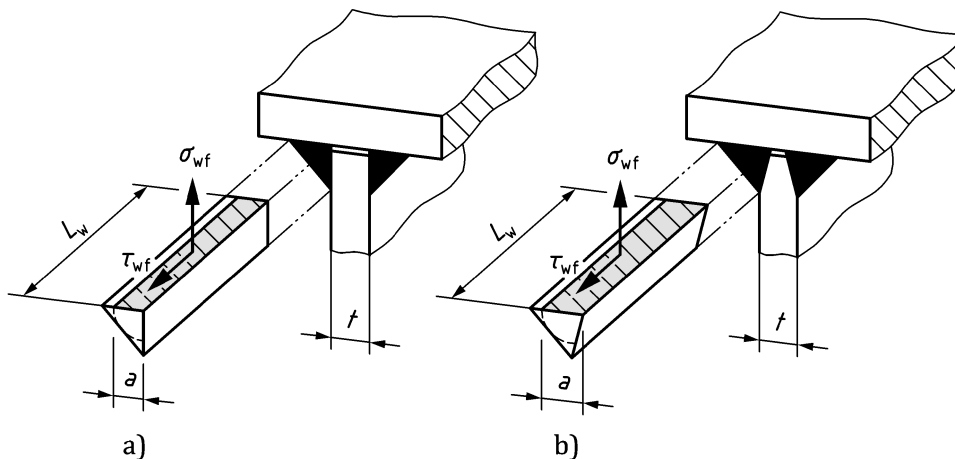


Figure 7.1 — Relevant stresses in a) fillet welds and b) partial penetration butt welds

(6) The nominal stresses σ_{wf} and τ_{wf} should be obtained by dividing the relevant component of the force transmitted per unit length of weld by the throat size a , see Figure 7.1.

(7) The stress components $\sigma_{\perp}$ and $\tau_{\perp}$ on the throat section (see Figure 7.2), determined by the directional approach according to EN 1993-1-8 due to a force F transverse to the longitudinal axis of the weld, may be transferred into the nominal stress component σ_{wf} of the weld by:

$$\sigma_{wf} = \sqrt{\sigma_{\perp}^2 + \tau_{\perp}^2} \quad (7.1)$$

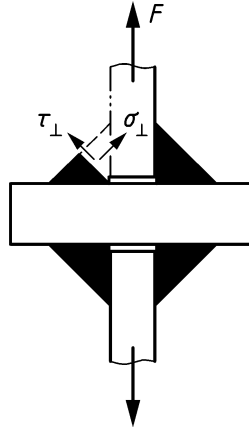


Figure 7.2 — Stresses on the throat section of fillet welds according to EN 1993-1-8

(8) The stress component $\tau_{||}$ on the throat section, determined by the directional approach according to EN 1993-1-8 due to a shear force parallel to the longitudinal axis of the weld, should be the nominal stress component τ_{wf} in the weld.

(9) The stress component $\sigma_{||}$ parallel to the longitudinal axis of the weld may be neglected for weld root failure.

(10) The relevant weld stress in double fillet welds due to transverse bending of the attached plate may be calculated using:

$$\sigma_{wf} = \frac{M}{a L_w (a + t)} \quad (7.2)$$

where:

- t is the thickness of the attached plate under bending
- a is the throat size of the weld
- M is the bending moment
- L_w is the weld length according to Figure 7.3

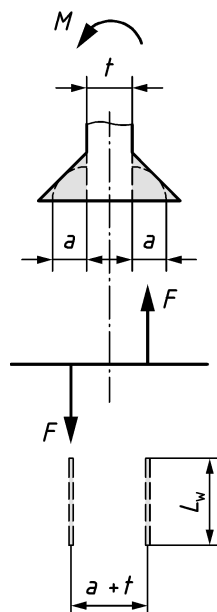


Figure 7.3 — Relevant stresses in double fillet welds due to transverse bending

(11) For bolted joints or joints with rods with rolled or cut threads, the relevant nominal stresses should be:

- nominal normal stresses
$$\sigma = \frac{F_B}{A_s} \quad (7.3)$$

- nominal shear stress on shank
$$\tau = \frac{V_B}{A} \quad (7.4)$$

where:

A is the area of the shank of the bolt or rod

A_s is the stress area of the bolt or rod

F_B is the force acting on the bolt or rod

V_B is the shear force per shear plane acting on the bolt or rod

NOTE For joints with preloaded bolts or rods:

- F_B can be determined according to Annex E,
- V_B can be disregarded.

(12) Prying and/or bending effects in bolted joints or joints with rods should be accounted for when determining the force F_B . Effects due to imperfections in the bolt or rod may be neglected.

(13) Prying and/or bending effects on the stress in the bolt may be neglected in simple and symmetric joints with preloaded bolts such as the T-stub in EN 1993-1-8, where the joined plates are either in full contact and have sufficient stiffness, or are without tip contact after assembly.

7.3 Calculation of nominal stress ranges

7.3.1 General

(1) Nominal stress ranges in relevant parts of constructional details should be determined at the locations indicated in the details shown in Table 10.1 to Table 10.12.

(2) Effective nominal stress ranges may be considered in the verification of non-welded or thermally stress-relieved welded constructional details in partial or total compression or in other constructional details with partial or total compression (including residual stresses) confirmed by modelling or measurements.

NOTE See 7.4 for effective nominal stress ranges.

7.3.2 Design value of nominal stress range

(1) For fatigue design situations where the fatigue action effect is defined by an equivalent constant stress range and where macro-geometric and/or concentrated load effects occur, the design value of the nominal stress ranges $\Delta\sigma_{e,2,Ed}$ and $\Delta\tau_{e,2,Ed}$ should be determined as follows:

$$\begin{aligned}\Delta\sigma_{e,2,Ed} &= \lambda_1 \lambda_2 \dots \lambda_n \Delta\sigma_E(\gamma_{ff} Q_{fat}) \\ \Delta\tau_{e,2,Ed} &= \lambda_1 \lambda_2 \dots \lambda_n \Delta\tau_E(\gamma_{ff} Q_{fat})\end{aligned}\quad (7.5)$$

where

λ_i are damage equivalent factors depending on, for example, the load situation and the structural characteristics ($i = 1, 2, \dots, n$)

(2) For fatigue design situations where the fatigue action effect is defined by an equivalent constant stress range, the design value of the modified nominal stress ranges $\Delta\sigma_{e,2,Ed}$ and $\Delta\tau_{e,2,Ed}$ should be determined as follows:

$$\begin{aligned}\Delta\sigma_{e,2,Ed} &= k_f \lambda_1 \lambda_2 \dots \lambda_n \Delta\sigma_E(\gamma_{ff} Q_{fat}) \\ \Delta\tau_{e,2,Ed} &= k_f \lambda_1 \lambda_2 \dots \lambda_n \Delta\tau_E(\gamma_{ff} Q_{fat})\end{aligned}\quad (7.6)$$

where

k_f is the stress concentration factor to take account of concentrated load and/or macro-geometric effects not included in the detail category

NOTE 1 See Figure 3.1 for examples of stress concentrations.

NOTE 2 Stress concentration factors k_f can be obtained from handbooks or from finite element calculations. Annex D gives stress concentration factors k_f for specific cases.

(3) For welded joints of structural hollow sections in lattice girders the design value of the modified nominal stress range $\Delta\sigma_{e,2,Ed}$ should be determined as follows using the simplified model in D.3 unless more accurate calculations are carried out:

$$\Delta\sigma_{e,2,Ed} = k_1 \Delta\sigma_{e,2,Ed}^{**} \quad (7.7)$$

where:

k_1 is the stress magnification factor according to Table D.1 and Table D.2