The European Union

EDICT OF GOVERNMENT

In order to promote public education and public safety, equal justice for all, a better informed citizenry, the rule of law, world trade and world peace, this legal document is hereby made available on a noncommercial basis, as it is the right of all humans to know and speak the laws that govern them.

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

1 General .................................................................................................................................................. 6
  1.1 Scope .............................................................................................................................................. 6
  1.2 Normative references ....................................................................................................................... 6
  1.3 Terms and definitions ....................................................................................................................... 6
  1.4 Symbols .......................................................................................................................................... 9

2 Basic requirements and methods ........................................................................................................ 9

3 Assessment methods .......................................................................................................................... 10

4 Stresses from fatigue actions ............................................................................................................. 11

5 Calculation of stresses ....................................................................................................................... 12

6 Calculation of stress ranges ................................................................................................................ 13
  6.1 General .......................................................................................................................................... 13
  6.2 Design value of nominal stress range ............................................................................................ 13
  6.3 Design value of modified nominal stress range ............................................................................ 14
  6.4 Design value of stress range for welded joints of hollow sections ................................................ 14
  6.5 Design value of stress range for geometrical (hot spot) stress .................................................... 14

7 Fatigue strength .................................................................................................................................. 14
  7.1 General .......................................................................................................................................... 14
  7.2 Fatigue strength modifications ....................................................................................................... 17

8 Fatigue verification .............................................................................................................................. 18


Annex B [normative] – Fatigue resistance using the geometric (hot spot) stress method ................. 33
Foreword

This European Standard EN 1993, Eurocode 3: Design of steel structures, has been prepared by Technical Committee CEN/TC 250 «Structural Eurocodes», the Secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes.

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 November 2005, and conflicting National Standards shall be withdrawn at latest by March 2010.

This Eurocode supersedes ENV 1993-1-1.

According to the CEN-CENELEC Internal Regulations, the National Standard Organizations of the following countries are bound to implement these European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Background to the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonization of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonized technical rules for the design of construction works which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980s.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links de facto the Eurocodes with the provisions of all the Council’s Directives and/or Commission’s Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products - CPD - and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

<table>
<thead>
<tr>
<th>Year</th>
<th>Eurocode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 1990</td>
<td>Eurocode 0:</td>
<td>Basis of Structural Design</td>
</tr>
<tr>
<td>EN 1991</td>
<td>Eurocode 1:</td>
<td>Actions on structures</td>
</tr>
<tr>
<td>EN 1992</td>
<td>Eurocode 2:</td>
<td>Design of concrete structures</td>
</tr>
<tr>
<td>EN 1993</td>
<td>Eurocode 3:</td>
<td>Design of steel structures</td>
</tr>
<tr>
<td>EN 1994</td>
<td>Eurocode 4:</td>
<td>Design of composite steel and concrete structures</td>
</tr>
<tr>
<td>EN 1995</td>
<td>Eurocode 5:</td>
<td>Design of timber structures</td>
</tr>
<tr>
<td>EN 1996</td>
<td>Eurocode 6:</td>
<td>Design of masonry structures</td>
</tr>
<tr>
<td>EN 1997</td>
<td>Eurocode 7:</td>
<td>Geotechnical design</td>
</tr>
<tr>
<td>EN 1998</td>
<td>Eurocode 8:</td>
<td>Design of structures for earthquake resistance</td>
</tr>
<tr>
<td>EN 1999</td>
<td>Eurocode 9:</td>
<td>Design of aluminium structures</td>
</tr>
</tbody>
</table>

1 Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).
Eurocode standards recognize the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

**Status and field of application of Eurocodes**

The Member States of the EU and EFTA recognize that Eurocodes serve as reference documents for the following purposes:

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement No 1 – Mechanical resistance and stability – and Essential Requirement No 2 – Safety in case of fire;
- as a basis for specifying contracts for construction works and related engineering services;
- as a framework for drawing up harmonized technical specifications for construction products (ENs and ETAs)

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents referring to in Article 12 of the CPD, although they are of a different nature from harmonized product standards. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

**National Standards implementing Eurocodes**

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National annex.

The National annex may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e.:

- values and/or classes where alternatives are given in the Eurocode,
- values to be used where a symbol only is given in the Eurocode,
- country specific data (geographical, climatic, etc.), e.g. snow map,
- the procedure to be used where alternative procedures are given in the Eurocode.

It may contain

- decisions on the application of informative annexes,
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

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2 According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonized ENs and ETAGs/ETAs.

3 According to Art. 12 of the CPD the interpretive documents shall:

a) give concrete form to the essential requirements by harmonizing the terminology and the technical bases and indicating classes or levels for each requirement where necessary;

b) indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc.;

c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, de facto, play a similar role in the field of the ER 1 and a part of ER 2.
Links between Eurocodes and harmonized technical specifications (ENs and ETAs) for products

There is a need for consistency between the harmonized technical specifications for construction products and the technical rules for works. Furthermore, all the information accompanying the CE Marking of the construction products which refer to Eurocodes should clearly mention which Nationally Determined Parameters have been taken into account.

National annex for EN 1993-1-9

This standard gives alternative procedures, values and recommendations with notes indicating where national choices may have to be made. The National Standard implementing EN 1993-1-9 should have a National Annex containing all Nationally Determined Parameters for the design of steel structures to be constructed in the relevant country.

National choice is allowed in EN 1993-1-9 through:

- 1.1(2)
- 2(2)
- 2(4)
- 3(2)
- 3(7)
- 5(2)
- 6.1(1)
- 6.2(2)
- 7.1(3)
- 7.1(5)
- 8(4)

\[^4\] see Art.3.3 and Art.12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.
1 General

1.1 Scope

(1) EN 1993-1-9 gives methods for the assessment of fatigue resistance of members, connections and joints subjected to fatigue loading.

(2) These methods are derived from fatigue tests 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).

NOTE 1 For tolerances see EN 1090. The choice of the execution standard may be given in the National Annex, until such time as EN 1090 is published.

NOTE 2 The National Annex may give supplementary information on inspection requirements during fabrication.

(3) The rules are applicable to structures where execution conforms with EN 1090.

NOTE Where appropriate, supplementary requirements are indicated in the detail category tables.

(4) The assessment methods given in this part are applicable to all grades of structural steels, stainless steels and unprotected weathering steels except where noted otherwise in the detail category tables. This part only applies to materials which conform to the toughness requirements of EN 1993-1-10.

(5) Fatigue assessment methods other than the Δσ-N methods as the notch strain method or fracture mechanics methods are not covered by this part.

(6) Post fabrication treatments to improve the fatigue strength other than stress relief are not covered in this part.

(7) The fatigue strengths given in this part apply to structures operating under normal atmospheric conditions and with sufficient corrosion protection and regular maintenance. The effect of seawater corrosion is not covered. Microstructural damage from high temperature (≥ 150 °C) is not covered.

1.2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

The following general standards are referred to in this standard.

EN 1090 Execution of steel structures – Technical requirements
EN 1990 Basis of structural design
EN 1991 Actions on structures
EN 1993 Design of Steel Structures
EN 1994-2 Design of Composite Steel and Concrete Structures: Part 2: Bridges

1.3 Terms and definitions

(1) For the purpose of this European Standard the following terms and definitions apply.
1.3.1 General

1.3.1.1 fatigue
The process of initiation and propagation of cracks through a structural part due to action of fluctuating stress.

1.3.1.2 nominal stress
A stress in the parent material or in a weld adjacent to a potential crack location calculated in accordance with elastic theory excluding all stress concentration effects.

NOTE The nominal stress as specified in this part can be a direct stress, a shear stress, a principal stress or an equivalent stress.

1.3.1.3 modified nominal stress
A nominal stress multiplied by an appropriate stress concentration factor $k_c$ to allow for a geometric discontinuity that has not been taken into account in the classification of a particular constructional detail.

1.3.1.4 geometric stress
hot spot stress
The maximum principal stress in the parent material adjacent to the weld toe, taking into account stress concentration effects due to the overall geometry of a particular constructional detail.

NOTE Local stress concentration effects e.g. from the weld profile shape (which is already included in the detail categories in Annex B) need not be considered.

1.3.1.5 residual stress
Residual stress is a permanent state of stress in a structure that is in static equilibrium and is independent of any applied action. Residual stresses can arise from rolling stresses, cutting processes, welding shrinkage or lack of fit between members or from any loading event that causes yielding of part of the structure.

1.3.2 Fatigue loading parameters

1.3.2.1 loading event
A defined loading sequence applied to the structure and giving rise to a stress history, which is normally repeated a defined number of times in the life of the structure.

1.3.2.2 stress history
A record or a calculation of the stress variation at a particular point in a structure during a loading event.

1.3.2.3 rainflow method
Particular cycle counting method of producing a stress-range spectrum from a given stress history.

1.3.2.4 reservoir method
Particular cycle counting method of producing a stress-range spectrum from a given stress history.

NOTE For the mathematical determination see annex A.

1.3.2.5 stress range
The algebraic difference between the two extremes of a particular stress cycle derived from a stress history.
1.3.2.6  
stress-range spectrum  
Histogram of the number of occurrences for all stress ranges of different magnitudes recorded or calculated for a particular loading event.

1.3.2.7  
design spectrum  
The total of all stress-range spectra in the design life of a structure relevant to the fatigue assessment.

1.3.2.8  
design life  
The reference period of time for which a structure is required to perform safely with an acceptable probability that failure by fatigue cracking will not occur.

1.3.2.9  
fatigue life  
The predicted period of time to cause fatigue failure under the application of the design spectrum.

1.3.2.10  
Miner's summation  
A linear cumulative damage calculation based on the Palmgren-Miner rule.

1.3.2.11  
equivalent constant amplitude stress range  
The constant-amplitude stress range that would result in the same fatigue life as for the design spectrum, when the comparison is based on a Miner's summation.

NOTE  For the mathematical determination see Annex A.

1.3.2.12  
fatigue loading  
A set of action parameters based on typical loading events described by the positions of loads, their magnitudes, frequencies of occurrence, sequence and relative phasing.

NOTE 1  The fatigue actions in EN 1991 are upper bound values based on evaluations of measurements of loading effects according to Annex A.

NOTE 2  The action parameters as given in EN 1991 are either  
- \( Q_{\text{max}}, n_{\text{max}} \), standardized spectrum or  
- \( Q_{\text{L,n}} \) related to \( n_{\text{max}} \) or  
- \( Q_{L,2} \) corresponding to \( n = 2 \times 10^6 \) cycles.  
Dynamic effects are included in these parameters unless otherwise stated.

1.3.2.13  
equivalent constant amplitude fatigue loading  
Simplified constant amplitude loading causing the same fatigue damage effects as a series of actual variable amplitude loading events

1.3.3  Fatigue strength

1.3.3.1  
fatigue strength curve  
The quantitative relationship between the stress range and number of stress cycles to fatigue failure, used for the fatigue assessment of a particular category of structural detail.

NOTE  The fatigue strengths given in this part are lower bound values based on the evaluation of fatigue tests with large scale test specimens in accordance with EN 1990 – Annex D.
1.3.3.2
detail category
The numerical designation given to a particular detail for a given direction of stress fluctuation, in order to indicate which fatigue strength curve is applicable for the fatigue assessment (The detail category number indicates the reference fatigue strength $\Delta\sigma_{C}$ in N/mm²).

1.3.3.3
constant amplitude fatigue limit
The limiting direct or shear stress range value below which no fatigue damage will occur in tests under constant amplitude stress conditions. Under variable amplitude conditions all stress ranges have to be below this limit for no fatigue damage to occur.

1.3.3.4
cut-off limit
Limit below which stress ranges of the design spectrum do not contribute to the calculated cumulative damage.

1.3.3.5
endurance
The life to failure expressed in cycles, under the action of a constant amplitude stress history.

1.3.3.6
reference fatigue strength
The constant amplitude stress range $\Delta\sigma_{C}$, for a particular detail category for an endurance $N = 2 \times 10^6$ cycles

1.4 Symbols
$\Delta\sigma$ stress range (direct stress)
$\Delta\tau$ stress range (shear stress)
$\Delta\sigma_{E1}$, $\Delta\tau_{E1}$ equivalent constant amplitude stress range related to $n_{max}$
$\Delta\sigma_{E2}$, $\Delta\tau_{E2}$ equivalent constant amplitude stress range related to 2 million cycles
$\Delta\sigma_{C}$, $\Delta\tau_{C}$ reference value of the fatigue strength at $N_{C} = 2$ million cycles
$\Delta\sigma_{D}$, $\Delta\tau_{D}$ fatigue limit for constant amplitude stress ranges at the number of cycles $N_{D}$
$\Delta\sigma_{F}$, $\Delta\tau_{F}$ cut-off limit for stress ranges at the number of cycle $N_{F}$
$\Delta\sigma_{eq}$ equivalent stress range for connections in webs of orthotropic decks
$\Delta\sigma_{red}$ reduced reference value of the fatigue strength
$\gamma_{f}$ partial factor for equivalent constant amplitude stress ranges $\Delta\sigma_{D}$, $\Delta\tau_{E}$
$\gamma_{Mf}$ partial factor for fatigue strength $\Delta\sigma_{C}$, $\Delta\tau_{C}$
m slope of fatigue strength curve
$\lambda_{d}$ damage equivalent factors
$\psi_{1}$ factor for frequent value of a variable action
$Q_{k}$ characteristic value of a single variable action
$k_{s}$ reduction factor for fatigue stress to account for size effects
$k_{m}$ magnification factor for nominal stress ranges to account for secondary bending moments in trusses
$k_{f}$ stress concentration factor
$N_{R}$ design life time expressed as number of cycles related to a constant stress range

2 Basic requirements and methods

Structural members shall be designed for fatigue such that there is an acceptable level of probability that their performance will be satisfactory throughout their design life.
NOTE Structures designed using fatigue actions from EN 1991 and fatigue resistance according to this part are deemed to satisfy this requirement.

(2) Annex A may be used to determine a specific loading model, if
- no fatigue load model is available in EN 1991,
- a more realistic fatigue load model is required.

NOTE Requirements for determining specific fatigue loading models may be specified in the National Annex.

(3) Fatigue tests may be carried out
- to determine the fatigue strength for details not included in this part,
- to determine the fatigue life of prototypes, for actual or for damage equivalent fatigue loads.

(4) In performing and evaluating fatigue tests EN 1990 should be taken into account (see also 7.1).

NOTE Requirements for determining fatigue strength from tests may be specified in the National Annex.

(5) The methods for the fatigue assessment given in this part follows the principle of design verification by comparing action effects and fatigue strengths; such a comparison is only possible when fatigue actions are determined with parameters of fatigue strengths contained in this standard.

(6) Fatigue actions are determined according to the requirements of the fatigue assessment. They are different from actions for ultimate limit state and serviceability limit state verifications.

NOTE Any fatigue cracks that develop during service life do not necessarily mean the end of the service life. Cracks should be repaired with particular care for execution to avoid introducing more severe notch conditions.

3 Assessment methods

(1) Fatigue assessment should be undertaken using either:
- damage tolerant method or
- safe life method.

(2) The damage tolerant method should provide an acceptable reliability that a structure will perform satisfactorily for its design life, provided that a prescribed inspection and maintenance regime for detecting and correcting fatigue damage is implemented throughout the design life of the structure.

NOTE 1 The damage tolerant method may be applied when in the event of fatigue damage occurring a load redistribution between components of structural elements can occur.

NOTE 2 The National Annex may give provisions for inspection programmes.

NOTE 3 Structures that are assessed to this part, the material of which is chosen according to EN 1993-1-10 and which are subjected to regular maintenance are deemed to be damage tolerant.

(3) The safe life method should provide an acceptable level of reliability that a structure will perform satisfactorily for its design life without the need for regular in-service inspection for fatigue damage. The safe life method should be applied in cases where local formation of cracks in one component could rapidly lead to failure of the structural element or structure.
(4) For the purpose of fatigue assessment using this part, an acceptable reliability level may be achieved by adjustment of the partial factor for fatigue strength $\gamma_{Mf}$ taking into account the consequences of failure and the design assessment used.

(5) Fatigue strengths are determined by considering the structural detail together with its metallurgical and geometric notch effects. In the fatigue details presented in this part the probable site of crack initiation is also indicated.

(6) The assessment methods presented in this code use fatigue resistance in terms of fatigue strength curves for
- standard details applicable to nominal stresses
- reference weld configurations applicable to geometric stresses.

(7) The required reliability can be achieved as follows:

a) damage tolerant method
- selecting details, materials and stress levels so that in the event of the formation of cracks a low rate of crack propagation and a long critical crack length would result,
- provision of multiple load path
- provision of crack-arresting details,
- provision of readily inspectable details during regular inspections.

b) safe-life method
- selecting details and stress levels resulting in a fatigue life sufficient to achieve the $\beta$-values to be at least equal to those required for ultimate limit state verifications at the end of the design service life.

**NOTE** The National Annex may give the choice of the assessment method, definitions of classes of consequences and numerical values for $\gamma_{Mf}$. Recommended values for $\gamma_{Mf}$ are given in Table 3.1.

**Table 3.1: Recommended values for partial factors for fatigue strength**

<table>
<thead>
<tr>
<th>Assessment method</th>
<th>Consequence of failure</th>
<th>Low consequence</th>
<th>High consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage tolerant</td>
<td></td>
<td>1.00</td>
<td>1.15</td>
</tr>
<tr>
<td>Safe life</td>
<td></td>
<td>1.15</td>
<td>1.35</td>
</tr>
</tbody>
</table>

4 Stresses from fatigue actions

(1) Modelling for nominal stresses should take into account all action effects including distortional effects and should be based on a linear elastic analysis for members and connections.

(2) For latticed girders made of hollow sections the modelling may be based on a simplified truss model with pinned connections. Provided that the stresses due to external loading applied to members between joints are taken into account the effects from secondary moments due to the stiffness of the connection can be allowed for by the use of $k_1$-factors (see Table 4.1 for circular hollow sections, Table 4.2 for rectangular hollow sections; these sections are subject to the geometrical restrictions according to Table 8.7).

**Table 4.1: $k_1$-factors for circular hollow sections under in-plane loading**

<table>
<thead>
<tr>
<th>Type of joint</th>
<th>Chords</th>
<th>Verticals</th>
<th>Diagonals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap joints</td>
<td>K type</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>N type / KT type</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Overlap joints</td>
<td>K type</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>N type / KT type</td>
<td>1.5</td>
<td>1.65</td>
</tr>
</tbody>
</table>
Table 4.2: k-factors for rectangular hollow sections under in-plane loading

<table>
<thead>
<tr>
<th>Type of joint</th>
<th>Chords</th>
<th>Verticals</th>
<th>Diagonals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap joints</td>
<td>K type</td>
<td>1.5</td>
<td>[4\xi] - [6\xi]</td>
</tr>
<tr>
<td></td>
<td>N type / KT type</td>
<td>1.5</td>
<td>2.2</td>
</tr>
<tr>
<td>Overlap joints</td>
<td>K type</td>
<td>1.5</td>
<td>[4\xi] - [6\xi]</td>
</tr>
<tr>
<td></td>
<td>N type / KT type</td>
<td>1.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**NOTE 1** For the definition of joint types see EN 1993-1-8.

**NOTE 2** Ranges of geometric validity:

For CHS planar joints (K-, N-, KT-joints):

\[0.3 \leq \beta \leq 0.60\]
\[12.0 \leq \gamma \leq 30.0\]
\[0.25 \leq \tau \leq 1.00\]
\[30^\circ \leq \theta \leq 60^\circ\]

For SHS joints (K-, N-, KT-joints):

\[0.40 \leq \beta \leq 0.60\]
\[6.25 \leq \gamma \leq 12.5\]
\[0.25 \leq \tau \leq 1.00\]
\[30^\circ \leq \theta \leq 60^\circ\]

### 5 Calculation of stresses

1. Stresses should be calculated at the serviceability limit state.
2. Class 4 cross sections are assessed for fatigue loads according to EN 1993-1-5.

**NOTE 1** For guidance see EN 1993-2 to EN 1993-6.

**NOTE 2** The National Annex may give limitations for class 4 sections.

3. Nominal stresses should be calculated at the site of potential fatigue initiation. Effects producing stress concentrations at details other than those included in Table 8.1 to Table 8.10 should be accounted for by using a stress concentration factor (SCF) according to 6.3 to give a modified nominal stress.

4. When using geometrical (hot spot) stress methods for details covered by Table B.1, the stresses should be calculated as shown in 6.5.

5. The relevant stresses for details in the parent material are:
   - nominal direct stresses \( \sigma \)
   - nominal shear stresses \( \tau \)

**NOTE** For effects of combined nominal stresses see 8(3).

6. The relevant stresses in the welds are (see Figure 5.1)
   - normal stresses \( \sigma_{wf} \) transverse to the axis of the weld: \( \sigma_{wf} = \sqrt{\sigma_{1f}^2 + \tau_{1f}^2} \)
   - shear stresses \( \tau_{wf} \) longitudinal to the axis of the weld: \( \tau_{wf} = \tau_{1f} \)

for which two separate checks should be performed.

**NOTE** The above procedure differs from the procedure given for the verification of fillet welds for the ultimate limit state, given in EN 1993-1-8.
6 Calculation of stress ranges

6.1 General

(1) The fatigue assessment should be carried out using
- nominal stress ranges for details shown in Table 8.1 to Table 8.10,
- modified nominal stress ranges where, e.g. abrupt changes of section occur close to the initiation site which are not included in Table 8.1 to Table 8.10 or
- geometric stress ranges where high stress gradients occur close to a weld toe in joints covered by Table B.1

NOTE The National Annex may give information on the use of the nominal stress ranges, modified nominal stress ranges or the geometric stress ranges. For detail categories for geometric stress ranges see Annex B.

(2) The design value of stress range to be used for the fatigue assessment should be the stress ranges \( \gamma_f \Delta \sigma_{E,2} \) corresponding to \( N_c = 2 \times 10^6 \) cycles.

6.2 Design value of nominal stress range

(1) The design value of nominal stress ranges \( \gamma_f \Delta \sigma_{E,2} \) and \( \gamma_f \Delta \tau_{E,2} \) should be determined as follows:

\[
\gamma_f \Delta \sigma_{E,2} = \lambda_1 \times \lambda_3 \times \lambda_t \times \ldots \times \lambda_m \times \Delta \sigma(\gamma_f Q_\lambda)
\]

\[
\gamma_f \Delta \tau_{E,2} = \lambda_1 \times \lambda_2 \times \lambda_t \times \ldots \times \lambda_m \times \Delta \tau(\gamma_f Q_\lambda)
\]

(6.1)

where \( \Delta \sigma(\gamma_f Q_\lambda) \), \( \Delta \tau(\gamma_f Q_\lambda) \) is the stress range caused by the fatigue loads specified in EN 1991

\( \lambda_i \) are damage equivalent factors depending on the spectra as specified in the relevant parts of EN 1993.

(2) Where no appropriate data for \( \lambda_i \) are available the design value of nominal stress range may be determined using the principles in Annex A.

NOTE The National Annex may give information supplementing Annex A.
6.3 Design value of modified nominal stress range

(1) The design value of modified nominal stress ranges $\gamma_{Tf} \Delta \sigma_{E,2}$ and $\gamma_{Tf} \Delta \tau_{E,2}$ should be determined as follows:

$$\gamma_{Tf} \Delta \sigma_{E,2} = k_r \times \lambda_1 \times \lambda_2 \times \lambda_3 \times ... \times \lambda_n \times \Delta \sigma(\gamma_{Tf}, Q_h)$$

$$\gamma_{Tf} \Delta \tau_{E,2} = k_r \times \lambda_1 \times \lambda_2 \times \lambda_3 \times ... \times \lambda_n \times \Delta \tau(\gamma_{Tf}, Q_h)$$

(6.2)

where $k_r$ is the stress concentration factor to take account of the local stress magnification in relation to detail geometry not included in the reference $\Delta \sigma_{R-N}$-curve.

NOTE $k_r$-values may be taken from handbooks or from appropriate finite element calculations.

6.4 Design value of stress range for welded joints of hollow sections

(1) Unless more accurate calculations are carried out the design value of modified nominal stress range $\gamma_{Tf} \Delta \sigma_{E,2}$ should be determined as follows using the simplified model in 4(2):

$$\gamma_{Tf} \Delta \sigma_{E,2} = k_1 (\gamma_{Tf} \Delta \sigma_{E,2}^*)$$

(6.3)

where $\gamma_{Tf} \Delta \sigma_{E,2}^*$ is the design value of stress range calculated with a simplified truss model with pinned joints.

$k_1$ is the magnification factor according to Table 4.1 and Table 4.2.

6.5 Design value of stress range for geometrical (hot spot) stress

(1) The design value of geometrical (hot spot) stress range $\gamma_{Tf} \Delta \sigma_{E,2}$ should be determined as follows:

$$\gamma_{Tf} \Delta \sigma_{E,2} = k_f (\gamma_{Tf} \Delta \sigma_{E,2}^*)$$

(6.4)

where $k_f$ is the stress concentration factor.

7 Fatigue strength

7.1 General

(1) The fatigue strength for nominal stress ranges is represented by a series of $(\log \Delta \sigma_{R}) - (\log N)$ curves and $(\log \Delta \tau_k) - (\log N)$ curves $(S-N$-curves), which correspond to typical detail categories. Each detail category is designated by a number which represents, in $N/mm^2$, the reference value $\Delta \sigma_{R}$ and $\Delta \tau_k$ for the fatigue strength at $2 \times 10^6$ cycles.

(2) For constant amplitude nominal stress ranges the fatigue strength can be obtained as follows:

$$\Delta \sigma_{R}^m N_R = \Delta \sigma_{C}^m 2 \times 10^6 \quad \text{with} \ m = 3 \ \text{for} \ N \leq 5 \times 10^6, \ \text{see Figure 7.1}$$

$$\Delta \tau_k^m N_R = \Delta \tau_k^m 2 \times 10^6 \quad \text{with} \ m = 5 \ \text{for} \ N \leq 10^8, \ \text{see Figure 7.2}$$

$$\Delta \sigma_{D} = \left( \frac{2}{5} \right)^{1/3} \Delta \sigma_{C} = 0.737 \Delta \sigma_{C} \quad \text{is the constant amplitude fatigue limit, see Figure 7.1, and}$$
\[ \Delta \tau_1 = \left( \frac{2}{100} \right)^{1/5} \Delta \tau_c = 0.457 \Delta \tau_c \] is the cut off limit, see Figure 7.2.

(3) For nominal stress spectra with stress ranges above and below the constant amplitude fatigue limit $$\Delta \sigma_D$$, the fatigue strength should be based on the extended fatigue strength curves as follows:

\[
\Delta \sigma_R = \Delta \sigma_{R}^{m} 2 \times 10^6 \quad \text{with } m = 3 \quad \text{for } N \leq 5 \times 10^6 \\
\Delta \sigma_R = \Delta \sigma_{R}^{m} 5 \times 10^9 \quad \text{with } m = 5 \quad \text{for } 5 \times 10^6 \leq N \leq 10^9
\]

\[ \Delta \sigma_L = \left( \frac{5}{100} \right)^{1/5} \Delta \sigma_D = 0.549 \Delta \sigma_D \] is the cut off limit, see Figure 7.1.

Figure 7.1: Fatigue strength curves for direct stress ranges

1 Detail category $$\Delta \sigma_C$$
2 Constant amplitude fatigue limit $$\Delta \sigma_D$$
3 Cut-off limit $$\Delta \sigma_L$$
NOTE 1 When test data were used to determine the appropriate detail category for a particular constructional detail, the value of the stress range $\Delta \sigma_c$ corresponding to a value of $N_c = 2$ million cycles were calculated for a 75% confidence level of 95% probability of survival for $\log N$, taking into account the standard deviation and the sample size and residual stress effects. The number of data points (not lower than 10) was considered in the statistical analysis, see annex D of EN 1990.

NOTE 2 The National Annex may permit the verification of a fatigue strength category for a particular application provided that it is evaluated in accordance with NOTE 1.

NOTE 3 Test data for some details do not exactly fit the fatigue strength curves in Figure 7.1. In order to ensure that non-conservative conditions are avoided, such details, marked with an asterisk, are located one detail category lower than their fatigue strength at $2 \times 10^6$ cycles would require. An alternative assessment may increase the classification of such details by one detail category provided that the constant amplitude fatigue limit $\Delta \sigma_D$ is defined as the fatigue strength at $10^7$ cycles for $m=3$ (see Figure 7.3).
Figure 7.3: Alternative strength $\Delta \sigma_c$ for details classified as $\Delta \sigma_c^*$

(4) Detail categories $\Delta \sigma_c$ and $\Delta t_c$ for nominal stresses are given in
Table 8.1 for plain members and mechanically fastened joints
Table 8.2 for welded built-up sections
Table 8.3 for transverse butt welds
Table 8.4 for weld attachments and stiffeners
Table 8.5 for load carrying welded joints
Table 8.6 for hollow sections
Table 8.7 for lattice girder node joints
Table 8.8 for orthotropic decks – closed stringers
Table 8.9 for orthotropic decks – open stringers
Table 8.10 for top flange to web junctions of runway beams

(5) The fatigue strength categories $\Delta \sigma_c$ for geometric stress ranges are given in Annex B.

NOTE The National Annex may give fatigue strength categories $\Delta \sigma_c$ and $\Delta t_c$ for details not covered by Table 8.1 to Table 8.10 and by Annex B.

7.2 Fatigue strength modifications

7.2.1 Non-welded or stress-relieved welded details in compression

(1) In non-welded details or stress-relieved welded details, the mean stress influence on the fatigue strength may be taken into account by determining a reduced effective stress range $\Delta \sigma = \Delta \sigma_{eff}$ in the fatigue assessment when part or all of the stress cycle is compressive.

(2) The effective stress range may be calculated by adding the tensile portion of the stress range and 60% of the magnitude of the compressive portion of the stress range, see Figure 7.4.
7.2.2 Size effect

(1) The size effect due to thickness or other dimensional effects should be taken into account as given in Table 8.1 to Table 8.10. The fatigue strength then is given by:

\[ \Delta \sigma_{C,\text{red}} = k_c \Delta \sigma_C \]  \hspace{1cm} (7.1)

8 Fatigue verification

(1) Nominal, modified nominal or geometric stress ranges due to frequent loads \( \psi_l \) \( Q_k \) (see EN 1990) should not exceed

\[ \Delta \sigma \leq 1.5 \sigma_y \]  \hspace{1cm} for direct stress ranges

\[ \Delta \tau \leq 1.5 \sigma_y / \sqrt{3} \]  \hspace{1cm} for shear stress ranges \hspace{1cm} (8.1)

(2) It should be verified that under fatigue loading

\[ \frac{\gamma_{Fi} \Delta \sigma_{E,2}}{\Delta \sigma_C / \gamma_{MI}} \leq 1.0 \]  \hspace{1cm} (8.2)

and

\[ \frac{\gamma_{Fi} \Delta \tau_{E,2}}{\Delta \tau_C / \gamma_{MI}} \leq 1.0 \]

NOTE Table 8.1 to Table 8.9 require stress ranges to be based on principal stresses for some details.

(3) Unless otherwise stated in the fatigue strength categories in Table 8.8 and Table 8.9, in the case of combined stress ranges \( \Delta \sigma_{E,2} \) and \( \Delta \tau_{E,2} \) it should be verified that:

\[ \left( \frac{\gamma_{Fi} \Delta \sigma_{E,2}}{\Delta \sigma_C / \gamma_{MI}} \right)^3 + \left( \frac{\gamma_{Fi} \Delta \tau_{E,2}}{\Delta \tau_C / \gamma_{MI}} \right)^3 \leq 1.0 \]  \hspace{1cm} (8.3)

(4) When no data for \( \Delta \sigma_{E,2} \) or \( \Delta \tau_{E,2} \) are available the verification format in Annex A may be used.
NOTE 1 Annex A is presented for stress ranges in longitudinal direction. This presentation may be adopted also for shear stress ranges.

NOTE 2 The National Annex may give information on the use of Annex A.
Table 8.1: Plain members and mechanically fastened joints

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>160</td>
<td>NOTE: The fatigue strength curve associated with category 160 is the highest. No detail can reach a better fatigue strength at any number of cycles.</td>
<td>Rolled or extruded products: 1) Plates and flats with as rolled edges; 2) Rolled sections with as rolled edges; 3) Seamless hollow sections, either rectangular or circular.</td>
<td>Details 1 to 7: Sharp edges, surface and rolling flaws to be improved by grinding until removed and smooth transition achieved.</td>
</tr>
<tr>
<td>140</td>
<td>Sheared or gas cut plates: 4) Machine gas cut or sheared material with subsequent dressing. 5) Material with machine gas cut edges having shallow and regular drag lines or manual gas cut material, subsequently dressed to remove all edge discontinuities. Machine gas cut with est quality according to EN 1090.</td>
<td>Details 6) and 7): Rolled or extruded products as in details 1), 2), 3)</td>
<td>Details 6) and 7): Any machinery scratches from grinding operations, can only be parallel to the stresses. Details 4) and 5): Re-entrant corners to be improved by grinding (slope ≤ 1/8) or evaluated using the appropriate stress concentration factors. - No repair by weld refill.</td>
</tr>
<tr>
<td>125</td>
<td>Rolled or extruded products as in details 1), 2), 3)</td>
<td>Details 1) to 5) made of weathering steel use the next lower category.</td>
<td></td>
</tr>
<tr>
<td>100 m = 5</td>
<td>Rolled or extruded products as in details 1), 2), 3)</td>
<td>8) Double covered symmetrical joint with preloaded high strength bolts.</td>
<td>8)Δm to be calculated on the gross cross-section.</td>
</tr>
<tr>
<td>112</td>
<td>Double covered symmetrical joint with preloaded injection bolts.</td>
<td>Double covered symmetrical joint with preloaded injection bolts.</td>
<td>8) ... gross cross-section.</td>
</tr>
<tr>
<td>90</td>
<td>Double covered joint with non-preloaded injection bolts.</td>
<td>Double covered joint with non-preloaded injection bolts.</td>
<td>9) ... net cross-section.</td>
</tr>
<tr>
<td>80</td>
<td>Double covered joint with fitted bolts.</td>
<td>Double covered joint with fitted bolts.</td>
<td>9) ... net cross-section.</td>
</tr>
<tr>
<td>50</td>
<td>Structural element with holes subject to bending and axial forces</td>
<td>Structural element with holes subject to bending and axial forces</td>
<td>11) ... net cross-section.</td>
</tr>
<tr>
<td>50 size effect for υ &gt; 30mm: k = (30/υ)0.23</td>
<td>Bolts and rods with rolled or cut threads in tension. For large diameters (anchor bolts) the size effect has to be taken into account with k,.</td>
<td>14)Δm to be calculated using the tensile stress area of the bolt. Bending and tension resulting from prying effects and bending stresses from other sources must be taken into account.</td>
<td></td>
</tr>
</tbody>
</table>

For detail 1) to 5) made of weathering steel use the next lower category.
### Table 8.1 (continued): Plain members and mechanically fastened joints

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 m=5</td>
<td>[Diagram]</td>
<td>Bolts in single or double shear. Thread not in the shear plane.</td>
<td>15) $\Delta$ calculated on the shank area of the bolt.</td>
</tr>
</tbody>
</table>

### Table 8.2: Welded built-up sections

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>[Diagram 1]</td>
<td>Continuous longitudinal welds. 1) Automatic or fully mechanized butt welds carried out from both sides. 2) Automatic or fully mechanized fillet welds. Cover plate ends to be checked using detail 6) or 7) in Table 8.5. 3) Automatic or fully mechanized fillet or butt welds carried out from both sides but containing stop/start positions. 4) Automatic or fully mechanized butt welds made from one side only, with a continuous backing bar, but without start/stop positions. 5) Manual fillet or butt weld. 6) Manual or automatic or fully mechanized butt welds carried out from one side only, particularly for box girders. 7) Repaired automatic or fully mechanized or manual fillet or butt welds for categories 1) to 6). 8) Intermittent longitudinal fillet welds. 9) Longitudinal butt weld, fillet weld or intermittent weld with a cope hole height not greater than 60 mm. For cope holes with a height $&gt; 40 \text{ mm}$ see detail 1) in Table 8.4. 10) Longitudinal butt weld, both sides ground flush parallel to load direction. 100% NDT. 11) Automatic or fully mechanized longitudinal seam weld without stop/start positions in hollow sections.</td>
<td>Details 11 and 7c. No stop/start position is permitted except when the repair is performed by a specialist and inspection is carried out to verify the proper execution of the repair.</td>
</tr>
</tbody>
</table>

For details 1 to 11 made with fully mechanized welding the categories for automatic welding apply.
### Table 8.3: Transverse butt welds

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructions detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>112</td>
<td><img src="image1" alt="Diagram" /></td>
<td>Without backing bar:  1) Transverse splices in plates and flats.  2) Flange and web splices in plate girders before assembly.  3) Full cross-section butt welds of rolled sections without cope holes.  4) Transverse splices in plates or flats tapered in width or in thickness, with a slope ≤ ¼.</td>
<td>- All welds ground flush to plate surface parallel to direction of the arrow.  - Weld run-on and run-off pieces to be used and subsequently removed, plate edges to be ground flush in direction of stress.  - Welded from both sides; checked by NDT.</td>
</tr>
<tr>
<td>90</td>
<td><img src="image2" alt="Diagram" /></td>
<td>Size effect for t &gt; 25mm:  $k_t = \left(\frac{25}{t}\right)^{0.2}$</td>
<td>Applies only to joints of rolled section, cut and welded.</td>
</tr>
<tr>
<td>90</td>
<td><img src="image3" alt="Diagram" /></td>
<td>As detail 3) but with cope holes.</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td><img src="image4" alt="Diagram" /></td>
<td>Size effect for t &gt; 25mm:  $k_t = \left(\frac{25}{t}\right)^{0.2}$</td>
<td>- The height of the weld convexity to be not greater than 20% of the weld width, with smooth transition to the plate surface.  - Weld run-on and run-off pieces to be used and subsequently removed, plate edges to be ground flush in direction of stress.  - Welded from both sides; checked by NDT.  - Rolled sections with the same dimensions without tolerance differences.</td>
</tr>
<tr>
<td>63</td>
<td><img src="image5" alt="Diagram" /></td>
<td>Full cross-section butt welds of rolled sections without cope hole.</td>
<td>- The height of the weld convexity to be not greater than 10% of the weld width, with smooth transition to the plate surface.  - Weld not ground flush.  - Weld run-on and run-off pieces to be used and subsequently removed, plate edges to be ground flush in direction of stress.  - Welded from both sides; checked by NDT.</td>
</tr>
</tbody>
</table>

8) As detail 3) but with cope holes.

9) Transverse splices in welded plate girders without cope hole.
10) Full cross-section butt welds of rolled sections with cope holes.
11) Transverse splices in plates, flats, rolled sections or plate girders.
12) Full cross-section butt welds of rolled sections without cope hole.

- Weld run-on and run-off pieces to be used and subsequently removed, plate edges to be ground flush in direction of stress.
- Welded from both sides.
Table 8.3 (continued): Transverse butt welds

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>size effect for (t&gt;25)mm: (k=\frac{25}{t}^{0.2})</td>
<td>13) Butt welds made from one side only.</td>
<td>13) Without backing strip.</td>
</tr>
<tr>
<td>71</td>
<td>size effect for (t&gt;25)mm: (k=\frac{25}{t}^{0.2})</td>
<td>With backing strip:</td>
<td>Details 14 and 15:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14) Transverse splice.</td>
<td>Fillet welds attaching the backing strip to terminate (\leq 10) mm from the edges of the stressed plate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15) Transverse butt weld tapered in width or thickness with a slope (\leq \frac{1}{4}).</td>
<td>Task welds inside the shape of butt welds.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Also valid for curved plates.</td>
<td></td>
</tr>
<tr>
<td>71</td>
<td>size effect for (t&gt;25)mm: (k=\frac{25}{t}^{0.2})</td>
<td>16) Transverse butt weld on a permanent backing strip tapered in width or thickness with a slope (\leq \frac{1}{4}). Also valid for curved plates.</td>
<td>16) Where backing strip fillet welds end (&lt; 10) mm from the plate edges, or if a good fit cannot be guaranteed.</td>
</tr>
<tr>
<td>50</td>
<td>size effect for (t&gt;25)mm and/or generalization for eccentricity: (k = \left(\frac{25}{t_1}\right)^{0.2} \left(1 + \frac{6}{t_1} \frac{t_1^{1/3}}{t_1^{2/3} + t_1^{1/3}}\right))</td>
<td>17) Transverse butt weld, different thicknesses without transition, centrelines aligned.</td>
<td>Details 18 and 19:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The fatigue strength of the continuous component has to be checked with Table 8.4, detail 4 or detail 5.</td>
<td></td>
</tr>
</tbody>
</table>

Table 8.4

1. Description

13) Bull welds made from one side only.

13) Butt welds made from one side only when full penetration checked by appropriate NDT.

14) Transverse splice.

15) Transverse butt weld tapered in width or thickness with a slope \(\leq \frac{1}{4}\). Also valid for curved plates.

16) Transverse butt weld on a permanent backing strip tapered in width or thickness with a slope \(\leq \frac{1}{4}\). Also valid for curved plates.

17) Transverse butt weld, different thicknesses without transition, centrelines aligned.

18) Transverse butt weld at intersecting flanges.

19) With transition radius according to Table 8.4, detail 4 or detail 5.
### Table 8.4: Weld attachments and stiffeners

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 L≤50mm</td>
<td><img src="image1" alt="Diagram" /></td>
<td>Longitudinal attachments: 1) The detail category varies according to the length of the attachment L.</td>
<td>The thickness of the attachment must be less than its height. If not see Table 8.5, details 5 or 6.</td>
</tr>
<tr>
<td>71 50&lt;L≤80mm</td>
<td><img src="image2" alt="Diagram" /></td>
<td>Longitudinal attachments to plate or tube.</td>
<td></td>
</tr>
<tr>
<td>63 80&lt;L≤100mm</td>
<td><img src="image3" alt="Diagram" /></td>
<td>Longitudinal fillet welded gusset with radius transition to plate or tube; end of fillet weld reinforced (full penetration); length of reinforced weld &gt; r.</td>
<td></td>
</tr>
<tr>
<td>56 L&gt;100mm or &lt;45°</td>
<td><img src="image4" alt="Diagram" /></td>
<td>2) Longitudinal attachments to plate or tube.</td>
<td></td>
</tr>
<tr>
<td>71 80mm</td>
<td><img src="image5" alt="Diagram" /></td>
<td>3) Longitudinal fillet welded gusset with radius transition to plate or tube; end of fillet weld reinforced (full penetration); length of reinforced weld &gt; r.</td>
<td></td>
</tr>
<tr>
<td>87 r=150mm</td>
<td><img src="image6" alt="Diagram" /></td>
<td>4) Gusset plate, welded to the edge of a plate or beam flange.</td>
<td>Details 31 and 41: Smooth transition radius r formed by initially machining or gas cutting the gusset plate before welding, then subsequently grinding the weld area parallel to the direction of the arrow so that the transverse weld toe is fully removed.</td>
</tr>
<tr>
<td>90 r=150mm or r&gt;150mm</td>
<td><img src="image7" alt="Diagram" /></td>
<td>Details 61 and 71: As welded, no radius transition</td>
<td></td>
</tr>
<tr>
<td>71 1/6&lt;r≤1/3</td>
<td><img src="image8" alt="Diagram" /></td>
<td>6) Welded to plate.</td>
<td></td>
</tr>
<tr>
<td>50 r&lt;1/6</td>
<td><img src="image9" alt="Diagram" /></td>
<td>7) Vertical stiffeners welded to a beam or plate girder.</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td><img src="image10" alt="Diagram" /></td>
<td>8) Diaphragm of box girders welded to the flange or the web. May not be possible for small hollow sections.</td>
<td></td>
</tr>
<tr>
<td>80 L≤50mm</td>
<td><img src="image11" alt="Diagram" /></td>
<td>9) The effect of welded shear studs on base material.</td>
<td></td>
</tr>
<tr>
<td>71 50&lt;L≤80mm</td>
<td><img src="image12" alt="Diagram" /></td>
<td>The values are also valid for ring stiffeners.</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td><img src="image13" alt="Diagram" /></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 8.5: Load carrying welded joints

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>Cracks and Tee joints: 1) Toe failure in full penetration but welds and all partial penetration joints.</td>
<td>1) Inspected and found free from discontinuities and misalignments outside the tolerances of EN 1090.</td>
</tr>
<tr>
<td>71</td>
<td>Flexible panel</td>
<td>2) For computing $\Delta t$, use modified nominal stress.</td>
</tr>
<tr>
<td>63</td>
<td>All t</td>
<td>3) In partial penetration joints two fatigue assessments are required. Firstly, root cracking is evaluated according to stresses defined in section 5, using category 36 for $\Delta t$, and category 80 for $\Delta t$. Secondly, toe cracking is evaluated by determining $\Delta t$ in the load-carrying plate.</td>
</tr>
<tr>
<td>56</td>
<td>120&lt;1&lt;200</td>
<td>Details 1) to 3): The misalignment of the load-carrying plate should not exceed 15% of the thickness of the intermediate plate.</td>
</tr>
<tr>
<td>50</td>
<td>200&lt;1&lt;300</td>
<td>4) $\Delta t$ in the main plate to be calculated on the basis of area shown in the sketch.</td>
</tr>
<tr>
<td>45</td>
<td>$t&gt;300$</td>
<td>5) $\Delta t$ to be calculated in the overlapping plates.</td>
</tr>
<tr>
<td>36*</td>
<td>Overlapped welded joints: 4) Fillet welded lap joint.</td>
<td>Details 4) and 5): - Weld terminations more than 10 mm from plate edge. - Shear cracking in the weld should be checked using detail 8).</td>
</tr>
<tr>
<td>45*</td>
<td>Cover plates in beams and plate girders.</td>
<td>6) If the cover plate is wider than the flange, a transverse end weld is needed. This weld should be carefully ground to remove undercut. The minimum length of the cover plate is 150 mm. For shorter attachments size effect see detail 1).</td>
</tr>
<tr>
<td>56*</td>
<td>Reinforced transverse end weld</td>
<td>7) Transverse end weld ground flash. In addition, if $t&gt;20$mm, front of plate at the end ground with a slope &lt; 1 in 4.</td>
</tr>
<tr>
<td>58</td>
<td>End zones of single or multiple welded cover plates, web or without transverse end weld.</td>
<td>8) Fillet welds transmitting a shear flow, such as web to flange welds in plate girders.</td>
</tr>
<tr>
<td>45</td>
<td>30&lt;1&lt;50</td>
<td>9) Fillet welded lap joint.</td>
</tr>
<tr>
<td>40</td>
<td>30&lt;1&lt;50</td>
<td>10) $\Delta t$ to be calculated from the nominal cross section of the stud.</td>
</tr>
<tr>
<td>36</td>
<td>$t&gt;50$</td>
<td>11) Weld toe ground. $\Delta t$ computed in tube.</td>
</tr>
<tr>
<td>58</td>
<td>20&lt;1&lt;50</td>
<td>12) Tube socket joint with fillet welds.</td>
</tr>
<tr>
<td>45</td>
<td>30&lt;1&lt;50</td>
<td>13) Tube socket joint with 80% full penetration butt welds.</td>
</tr>
<tr>
<td>40</td>
<td>$t&gt;300$</td>
<td>14) $\Delta t$ computed in tube.</td>
</tr>
</tbody>
</table>

**BS EN 1993-1-9 : 2005**

EN 1993-1-9 : 2005 (E)

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**Table 8.5**: **Load carrying welded joints**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>Cracks and Tee joints: 1) Toe failure in full penetration but welds and all partial penetration joints.</td>
<td>1) Inspected and found free from discontinuities and misalignments outside the tolerances of EN 1090.</td>
</tr>
<tr>
<td>71</td>
<td>Flexible panel</td>
<td>2) For computing $\Delta t$, use modified nominal stress.</td>
</tr>
<tr>
<td>63</td>
<td>All t</td>
<td>3) In partial penetration joints two fatigue assessments are required. Firstly, root cracking is evaluated according to stresses defined in section 5, using category 36 for $\Delta t$, and category 80 for $\Delta t$. Secondly, toe cracking is evaluated by determining $\Delta t$ in the load-carrying plate.</td>
</tr>
<tr>
<td>56</td>
<td>120&lt;1&lt;200</td>
<td>Details 1) to 3): The misalignment of the load-carrying plate should not exceed 15% of the thickness of the intermediate plate.</td>
</tr>
<tr>
<td>50</td>
<td>200&lt;1&lt;300</td>
<td>4) $\Delta t$ in the main plate to be calculated on the basis of area shown in the sketch.</td>
</tr>
<tr>
<td>45</td>
<td>$t&gt;300$</td>
<td>5) $\Delta t$ to be calculated in the overlapping plates.</td>
</tr>
<tr>
<td>36*</td>
<td>Overlapped welded joints: 4) Fillet welded lap joint.</td>
<td>Details 4) and 5): - Weld terminations more than 10 mm from plate edge. - Shear cracking in the weld should be checked using detail 8).</td>
</tr>
<tr>
<td>45*</td>
<td>Cover plates in beams and plate girders.</td>
<td>6) If the cover plate is wider than the flange, a transverse end weld is needed. This weld should be carefully ground to remove undercut. The minimum length of the cover plate is 150 mm. For shorter attachments size effect see detail 1).</td>
</tr>
<tr>
<td>56*</td>
<td>Reinforced transverse end weld</td>
<td>7) Transverse end weld ground flash. In addition, if $t&gt;20$mm, front of plate at the end ground with a slope &lt; 1 in 4.</td>
</tr>
<tr>
<td>58</td>
<td>End zones of single or multiple welded cover plates, web or without transverse end weld.</td>
<td>8) Fillet welds transmitting a shear flow, such as web to flange welds in plate girders.</td>
</tr>
<tr>
<td>45</td>
<td>30&lt;1&lt;50</td>
<td>9) Fillet welded lap joint.</td>
</tr>
<tr>
<td>40</td>
<td>30&lt;1&lt;50</td>
<td>10) $\Delta t$ to be calculated from the nominal cross section of the stud.</td>
</tr>
<tr>
<td>36</td>
<td>$t&gt;50$</td>
<td>11) Weld toe ground. $\Delta t$ computed in tube.</td>
</tr>
<tr>
<td>58</td>
<td>20&lt;1&lt;50</td>
<td>12) Tube socket joint with fillet welds.</td>
</tr>
<tr>
<td>45</td>
<td>30&lt;1&lt;50</td>
<td>13) Tube socket joint with 80% full penetration butt welds.</td>
</tr>
<tr>
<td>40</td>
<td>$t&gt;300$</td>
<td>14) $\Delta t$ computed in tube.</td>
</tr>
</tbody>
</table>
### Table 8.6: Hollow sections (t ≤ 12.5 mm)

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td><img src="1" alt="Diagram" /></td>
<td>1) Tube-plate joint, tubes fluted, butt weld (x-groove)</td>
<td>1) $\Delta t$ computed in tube. Only valid for tube diameter less than 200 mm.</td>
</tr>
<tr>
<td>71</td>
<td><img src="2" alt="Diagram" /></td>
<td>2) Tube-plate joint, tube slotted and welded to plate. Holes at end of slit.</td>
<td>2) $\Delta t$ computed in tube. Shear cracking in the weld should be verified using Table 8.5, detail 8.</td>
</tr>
<tr>
<td>63</td>
<td><img src="3" alt="Diagram" /></td>
<td>Transverse butt welds.</td>
<td>Details 3) and 4):</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) Butt-welded end-to-end connections between circular structural hollow sections.</td>
<td>- Weld convexity ≤ 10% of weld width, with smooth transitions.</td>
</tr>
<tr>
<td></td>
<td><img src="4" alt="Diagram" /></td>
<td>4) Butt-welded end-to-end connections between rectangular structural hollow sections.</td>
<td>- Welded in flat position, inspected and found free from defects outside the tolerances EN 1090.</td>
</tr>
<tr>
<td>70</td>
<td><img src="5" alt="Diagram" /></td>
<td>Welded attachments:</td>
<td>Details 5) and 7):</td>
</tr>
<tr>
<td></td>
<td><img src="6" alt="Diagram" /></td>
<td>5) Circular or rectangular structural hollow section, fillet-welded to another section.</td>
<td>- Non load-carrying welds.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6) Circular structural hollow sections, butt-welded end-to-end with an intermediate plate.</td>
<td>- Width parallel to stress direction $t \leq 100$ mm.</td>
</tr>
<tr>
<td></td>
<td><img src="7" alt="Diagram" /></td>
<td>7) Rectangular structural hollow sections, butt-welded end-to-end with an intermediate plate.</td>
<td>- Other cases see Table 8.4.</td>
</tr>
<tr>
<td>45</td>
<td><img src="8" alt="Diagram" /></td>
<td>8) Circular structural hollow sections, fillet-welded end-to-end with an intermediate plate.</td>
<td>Details 8) and 9):</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9) Rectangular structural hollow sections, fillet-welded end-to-end with an intermediate plate.</td>
<td>- Load-carrying welds.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Wall thickness $t \leq 8$ mm.</td>
</tr>
</tbody>
</table>
### Table 8.7: Lattice girder node joints

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 m=3</td>
<td>Gap joints: Detail 1): K and N joints, circular structural hollow sections:</td>
<td>Details 1 and 2):</td>
</tr>
<tr>
<td></td>
<td>(t_h \geq 2.0)  (t_l)</td>
<td>- Separate assessments needed for the chords and the braces.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For intermediate values of the ratio (t_h/t_l), interpolate linearly between detail categories.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Fillet welds permitted for braces with wall thickness (t_l \leq 8) mm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (t_h \leq 8) mm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (35^\circ \leq \theta \leq 50^\circ).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (h_d/t_h \leq 25)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (d_h/t_h \leq 25)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (0.4 \leq b_d/b_h \leq 1.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (0.25 \leq d_h/d_l \leq 1.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (b_h \leq 200) mm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (d_h \leq 300) mm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (0.5h_d \leq e_y \leq 0.25b_h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (0.5d_h \leq e_y \leq 0.25d_l)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- (e_y \leq 0.02d_h) or (e_y \leq 0.02d_l).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[(e_y) is out-of-plane eccentricity].</td>
</tr>
<tr>
<td>45 m=3</td>
<td>Gap joints: Detail 2): K and N joints, rectangular structural hollow sections:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(t_h \geq 1.0)  (t_l)</td>
<td></td>
</tr>
<tr>
<td>71 m=3</td>
<td>Gap joints: Detail 2): K and N joints, rectangular structural hollow sections:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(t_h \geq 2.0)  (t_l)</td>
<td></td>
</tr>
<tr>
<td>36 m=3</td>
<td>Overlap joints: Detail 3): K joints, circular or rectangular structural hollow sections:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(t_h \geq 1.0)  (t_l)</td>
<td></td>
</tr>
<tr>
<td>71 m=3</td>
<td>Overlap joints: Detail 3): K joints, circular or rectangular structural hollow sections:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(t_h \geq 1.4)  (t_l)</td>
<td></td>
</tr>
<tr>
<td>56 m=3</td>
<td>Overlap joints: Detail 4): N joints, circular or rectangular structural hollow sections:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(t_h \geq 1.0)  (t_l)</td>
<td></td>
</tr>
<tr>
<td>71 m=3</td>
<td>Overlap joints: Detail 4): N joints, circular or rectangular structural hollow sections:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(t_h \geq 1.4)  (t_l)</td>
<td></td>
</tr>
</tbody>
</table>

**Definition of \(p\) and \(q\):**

\[
p = \frac{p}{t_l} \quad \text{and} \quad q = \frac{q}{t_l}
\]
### Table 8.8: Orthotropic decks – closed stringers

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 t≤12mm</td>
<td><img src="image" alt="Detail 1" /></td>
<td>1) Continuous longitudinal stringer, with additional cutout in cross girder.</td>
<td>1) Assessment based on the direct stress range $\Delta \sigma$ in the longitudinal stringer.</td>
</tr>
<tr>
<td>71 t&gt;12mm</td>
<td><img src="image" alt="Detail 2" /></td>
<td>2) Continuous longitudinal stringer, no additional cutout in cross girder.</td>
<td>2) Assessment based on the direct stress range $\Delta \sigma$ in the stringer.</td>
</tr>
<tr>
<td>80 t≤12mm</td>
<td><img src="image" alt="Detail 3" /></td>
<td>3) Separate longitudinal stringer each side of the cross girder.</td>
<td>3) Assessment based on the direct stress range $\Delta \sigma$ in the stringer.</td>
</tr>
<tr>
<td>71 t&gt;12mm</td>
<td><img src="image" alt="Detail 4" /></td>
<td>4) Joint in rib, full penetration butt weld with steel backing plate.</td>
<td>4) Assessment based on the direct stress range $\Delta \sigma$ in the stringer.</td>
</tr>
<tr>
<td>112</td>
<td>As detail 1, 2, 4 in Table 8.3</td>
<td>5) Full penetration butt weld in rib, welded from both sides, without backing plate.</td>
<td>5) Assessment based on the direct stress range $\Delta \sigma$ in the stringer. Tack welds inside the shape of butt welds.</td>
</tr>
<tr>
<td>90</td>
<td>As detail 5, 7 in Table 8.3</td>
<td>6) Critical section in web of cross girder due to cut outs.</td>
<td>6) Assessment based on stress range in critical section taking account of Vierendeel effects.</td>
</tr>
<tr>
<td>80</td>
<td>As detail 9, 11 in Table 8.3</td>
<td>7) Partial penetration weld with $a \geq t$</td>
<td>7) Assessment based on direct stress range from bending in the plate.</td>
</tr>
<tr>
<td>71</td>
<td><img src="image" alt="Detail 6" /></td>
<td>Weld connecting deck plate to trapezoidal or V-section rib</td>
<td>8) Fillet weld or partial penetration weld out of the range of detail 7)</td>
</tr>
<tr>
<td>50</td>
<td><img src="image" alt="Detail 8" /></td>
<td>$\Delta \sigma = \frac{\Delta M}{W_u}$</td>
<td>8) Assessment based on direct stress range from bending in the plate.</td>
</tr>
</tbody>
</table>

**NOTE:** In case the stress range is determined according to EN 1993-2, 9.4.2.2.3b, detail category 112 may be used.
### Table 8.9: Orthotropic decks – open stringers

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 t≤12mm</td>
<td><img src="image1" alt="Diagram" /></td>
<td>1) Connection of longitudinal stringer to cross girder.</td>
<td>1) Assessment based on the direct stress range $\Delta \sigma$ in the stringer.</td>
</tr>
<tr>
<td>71 t&gt;12mm</td>
<td><img src="image2" alt="Diagram" /></td>
<td>2) Connection of continuous longitudinal stringer to cross girder. $\Delta \sigma = \frac{\Delta M}{W_{\text{web}}}$, $\Delta \tau = \frac{\Delta V}{A_{\text{web}}}$</td>
<td>2) Assessment based on combining the shear stress range $\Delta \tau$ and direct stress range $\Delta \sigma$ in the web of the cross girder, as an equivalent stress range: $\Delta \sigma_{\text{eq}} = \frac{1}{2} \left( \Delta \sigma + \sqrt{\Delta \sigma^2 + 4 \Delta \tau^2} \right)$</td>
</tr>
</tbody>
</table>

Check also stress range between stringers as defined in EN 1993-2.

### Table 8.10: Top flange to web junction of runway beams

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>160</td>
<td><img src="image3" alt="Diagram" /></td>
<td>1) Rolled L- or H-sections</td>
<td>1) Vertical compressive stress range $\Delta \sigma_{\text{web}}$ in web due to wheel loads</td>
</tr>
<tr>
<td>71</td>
<td><img src="image4" alt="Diagram" /></td>
<td>2) Full penetration tee-butt weld</td>
<td>2) Vertical compressive stress range $\Delta \sigma_{\text{web}}$ in web due to wheel loads</td>
</tr>
<tr>
<td>36*</td>
<td><img src="image5" alt="Diagram" /></td>
<td>3) Partial penetration tee-butt welds, or effective full penetration tee-butt welds conforming with EN 1993-1-8</td>
<td>3) Stress range $\Delta \sigma_{\text{web}}$ in web due to wheel loads</td>
</tr>
<tr>
<td>36*</td>
<td><img src="image6" alt="Diagram" /></td>
<td>4) Fillet welds</td>
<td>4) Stress range $\Delta \sigma_{\text{thrust}}$ in web due to vertical compression from wheel loads</td>
</tr>
<tr>
<td>36*</td>
<td><img src="image7" alt="Diagram" /></td>
<td>5) T-section flange with full penetration tee-butt weld</td>
<td>5) Vertical compressive stress range $\Delta \sigma_{\text{thrust}}$ in web due to wheel loads</td>
</tr>
<tr>
<td>71</td>
<td><img src="image8" alt="Diagram" /></td>
<td>6) T-section flange with partial penetration tee-butt weld, or effective full penetration tee-butt weld conforming with EN 1993-1-8</td>
<td>6) Stress range $\Delta \sigma_{\text{thrust}}$ in weld due to vertical compression from wheel loads</td>
</tr>
<tr>
<td>36*</td>
<td><img src="image9" alt="Diagram" /></td>
<td>7) T-section flange with fillet welds</td>
<td>7) Stress range $\Delta \sigma_{\text{thrust}}$ in weld due to vertical compression from wheel loads</td>
</tr>
</tbody>
</table>

A.1 Determination of loading events

(1) Typical loading sequences that represent a credible estimated upper bound of all service load events expected during the fatigue design life should be determined using prior knowledge from similar structures, see Figure A.1 a).

A.2 Stress history at detail

(1) A stress history should be determined from the loading events at the structural detail under consideration taking account of the type and shape of the relevant influence lines to be considered and the effects of dynamic magnification of the structural response, see Figure A.1 b).

(2) Stress histories may also be determined from measurements on similar structures or from dynamic calculations of the structural response.

A.3 Cycle counting

(1) Stress histories may be evaluated by either of the following cycle counting methods:
   - rainflow method
   - reservoir method, see Figure A.1 c).

   to determine
   - stress ranges and their numbers of cycles
   - mean stresses, where the mean stress influence needs to be taken into account.

A.4 Stress range spectrum

(1) The stress range spectrum should be determined by presenting the stress ranges and the associated number of cycles in descending order, see Figure A.1 d).

(2) Stress range spectra may be modified by neglecting peak values of stress ranges representing less than 1% of the total damage and small stress ranges below the cut off limit.

(3) Stress range spectra may be standardized according to their shape, e.g. with the coordinates $\Delta \sigma = 1,0$ and $\Sigma n = 1,0$. 

A.5 Cycles to failure

(1) When using the design spectrum the applied stress ranges $\Delta \sigma_i$ should be multiplied by $\gamma_{f\ell}$ and the fatigue strength values $\Delta \sigma_c$ divided by $\gamma_{Mf}$ in order to obtain the endurance value $N_{Ri}$ for each band in the spectrum. The damage $D_d$ during the design life should be calculated from:

$$D_d = \sum \frac{n_{Ei}}{N_{Ri}} \quad \text{(A.1)}$$

where $n_{Ei}$ is the number of cycles associated with the stress range $\gamma_{f\ell} \Delta \sigma_i$ for band $i$ in the factored spectrum.

$N_{Ri}$ is the endurance (in cycles) obtained from the factored $\frac{\Delta \sigma_c}{\gamma_{Mf}}$ curve for a stress range of $\gamma_{f\ell} \Delta \sigma_i$.

(2) On the basis of equivalence of $D_d$ the design stress range spectrum may be transformed into any equivalent design stress range spectrum, e.g. a constant amplitude design stress range spectrum yielding the fatigue equivalent load $Q_e$ associated with the cycle number $n_{max} = \sum n_i$ or $Q_{E.2}$ associated with the cycle number $N_c = 2 \times 10^6$.

A.6 Verification formats

(1) The fatigue assessment based on damage accumulation should meet the following criteria:

- based on damage accumulation:

$$D_d \leq 1.0 \quad \text{(A.2)}$$

- based on stress range:

$$\gamma_{f\ell} \Delta \sigma_{E.2} \leq \sqrt{D_d} \frac{\Delta \sigma_c}{\gamma_{Mf}} \quad \text{where } m = 3 \quad \text{(A.3)}$$
a) Loading sequence:
Typical load cycle (repeated n-times in the design life)

b) Stress history at detail

c) Cycle counting (e.g. reservoir method)

d) Stress range spectrum

e) Cycles to failure

f) Damage summation
(Palmgren-Miner rule)

\[ \sum \frac{n_i}{N_i} = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \frac{n_4}{N_4} \leq D_L \]

Figure A.1: Cumulative damage method
Annex B [normative] – Fatigue resistance using the geometric (hot spot) stress method

(1) For the application of the geometric stress method detail categories are given in Table B.1 for cracks initiating from
- toes of butt welds,
- toes of fillet welded attachments,
- toes of fillet welds in cruciform joints.

Table B.1: Detail categories for use with geometric (hot spot) stress method

<table>
<thead>
<tr>
<th>Detail category</th>
<th>Constructional detail</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>112</td>
<td>1</td>
<td>1) Full penetration butt joint.</td>
<td>1) All welds ground flush to plate surface parallel to direction of the arrow. - Weld run-on and run-off pieces to be used and subsequently removed, plate edges to be ground flush in direction of stress. - Welded from both sides, checked by NDT. - For misalignment see NOTE 1.</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
<td>2) Full penetration butt joint.</td>
<td>2) Weld not ground flush - Weld run-on and run-off pieces to be used and subsequently removed, plate edges to be ground flush in direction of stress. - Welded from both sides. - For misalignment see NOTE 1.</td>
</tr>
<tr>
<td>100</td>
<td>3</td>
<td>3) Cruciform joint with full penetration K-butt welds.</td>
<td>3) Weld toe angle ≤60° - For misalignment see NOTE 1.</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>4) Non load-carrying fillet welds.</td>
<td>4) Weld toe angle ≤60°. - See also NOTE 2.</td>
</tr>
<tr>
<td>100</td>
<td>5</td>
<td>5) Bracket ends, ends of longitudinal stiffeners.</td>
<td>5) Weld toe angle ≤60°. - See also NOTE 2.</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>6) Cover plate ends and similar joints.</td>
<td>6) Weld toe angle ≤60°. - See also NOTE 2.</td>
</tr>
<tr>
<td>90</td>
<td>7</td>
<td>7) Cruciform joints with load-carrying fillet welds.</td>
<td>7) Weld toe angle ≤60°. - For misalignment see NOTE 1. - See also NOTE 2.</td>
</tr>
</tbody>
</table>

NOTE 1 Table B.1 does not cover effects of misalignment. They have to be considered explicitly in determination of stress.

NOTE 2 Table B.1 does not cover fatigue initiation from the root followed by propagation through the throat.
NOTE 3 For the definition of the weld toe angle see EN 1090.