SLOVENSKI STANDARD
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Evrokod 3: Projektiranje jeklenih konstrukcij – 1-9. del: Utrujanje

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

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

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

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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 23 April 2004.

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Contents

Foreword

This European Standard EN 1993, Eurocode 3: Design of steel structures, has been prepared by Technical Committee CEN/TC250 « Structural Eurocodes », the Secretariat of which is held by BSI. CEN/TC250 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of an identical text or by endorsement, at the latest by November 2005, and conflicting National Standards shall be withdrawn at latest by March 2010.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[1] 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:

EN 1990	Eurocode 0:	Basis of Structural 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

[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 N°1 – Mechanical resistance and stability – and Essential Requirement N°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[2] referred to in Article 12 of the CPD, although they are of a different nature from harmonized product standards[3]. 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 interpretative 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 harmonized 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[4]. 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 $\Delta\sigma_R$-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_f, 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_{max}, n_{max}, standardized spectrum or
- $Q_{E,n_{max}}$ related to n_{max} or
- $Q_{E,2}$ corresponding to $n = 2\times10^6$ 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 $N = 2\times10^6$ cycles

1.4 Symbols

$\Delta\sigma$	stress range (direct stress)
$\Delta\tau$	stress range (shear stress)
$\Delta\sigma_E$, $\Delta\tau_E$	equivalent constant amplitude stress range related to n_{max}
$\Delta\sigma_{E,2}$, $\Delta\tau_{E,2}$	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
$\Delta\sigma_L$, $\Delta\tau_L$	cut-off limit for stress ranges at the number of cycle N_L
$\Delta\sigma_{eq}$	equivalent stress range for connections in webs of orthotropic decks
$\Delta\sigma_{C,red}$	reduced reference value of the fatigue strength
γ_{Ff}	partial factor for equivalent constant amplitude stress ranges $\Delta\sigma_E$, $\Delta\tau_E$
γ_{Mf}	partial factor for fatigue strength $\Delta\sigma_C$, $\Delta\tau_C$
m	slope of fatigue strength curve
λ_i	damage equivalent factors
ψ_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_1	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

(1) Structural members should 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.