# SLOVENSKI STANDARD
# SIST EN 1999-1-3:2007/kFprA1:2011

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**Evrokod 9: Projektiranje konstrukcij iz aluminijevih zlitin - 1-3. del: Konstrukcije, občutljive na utrujanje**

Eurocode 9: Design of aluminium structures - Part 1-3: Structures susceptible to fatigue

Eurocode 9: Bemessung und Konstruktion von Aluminiumtragwerken - Teil 1-3: Ermüdungsbeanspruchte Tragwerke



Eurocode 9: Calcul des structures en aluminium - Partie 1-3: Structures sensibles à la fatigue



**Ta slovenski standard je istoveten z:** **EN 1999-1-3:2007/FprA1**

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**ICS:**

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| 91.080.10 | Kovinske konstrukcije | Metal structures |

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# Eurocode 9: Design of aluminium structures - Part 1-3: Structures susceptible to fatigue

Eurocode 9: Calcul des structures en aluminium - Partie 1-3: Structures sensibles à la fatigue

Eurocode 9: Bemessung und Konstruktion von Aluminiumtragwerken - Teil 1-3: Ermüdungsbeanspruchte Tragwerke

This draft amendment is submitted to CEN members for unique acceptance procedure. It has been drawn up by the Technical Committee CEN/TC 250.

This draft amendment A1, if approved, will modify the European Standard EN 1999-1-3:2007. If this draft becomes an amendment, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for inclusion of this amendment into the relevant national standard without any alteration.



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# Foreword

This document (EN 1999-1-3:2007/FprA1:2010) has been prepared by Technical Committee CEN/TC 250 "Structural Eurocodes", the secretariat of which is held by BSI.

This document is currently submitted to the Unique Acceptance Procedure.

## 1 Modification to 1.5.2.34

*Replace 1.5.2.34 with the following: "*

**1.5.2.34**
**safe life**
period of time for which a structure is estimated to perform safely with an acceptable probability that failure by fatigue cracking will not occur, when using the safe life design method".

## 2 Modification to 1.6

*In 1.6 replace*

"$\Delta\sigma$ nominal stress range (normal stress)

$\Delta\tau$ effective shear stress range

$\Delta\sigma_C$ reference fatigue strength at 2x10[6] cycles (normal stress)

$\Delta\sigma_D$ constant amplitude fatigue limit

$\Delta\sigma_E$ equivalent constant amplitude stress range related to $N_{max}$

$\Delta\sigma_{E,2}$ equivalent constant amplitude stress range related to 2x10[6] cycles



$\Delta\sigma_L$ cut-off limit

$\Delta\sigma_R$ fatigue strength (normal stress)



$\sigma_{max}$, $\sigma_{min}$ maximum and minimum values of the fluctuating stresses in a stress cycle



$\sigma_m$ mean stress."

*with*

"$\Delta\sigma$ nominal stress range (normal stress)

NOTE $\Delta\sigma$ refers either to action effects or to fatigue strength depending on context.

$\Delta\tau$ effective shear stress range

$\Delta\sigma_C$ reference fatigue strength at $2 \times 10^6$ cycles (normal stress)

$\Delta\sigma_D$ constant amplitude fatigue limit

$\Delta\sigma_E$ nominal stress range from fatigue actions

$\Delta\sigma_{E,Ne}$ equivalent constant amplitude stress range related to $N_{max}$

$\Delta\sigma_{E,2e}$ equivalent constant amplitude stress range related to $2 \times 10^6$ cycles

$\Delta\sigma_L$ cut-off limit

$\Delta\sigma_R$ fatigue strength (normal stress)

$\sigma_{max}$, $\sigma_{min}$ maximum and minimum values of the fluctuating stresses in a stress cycle

$\sigma_m$ mean stress."

*and add*

"$D_{L.d}$ design fatigue damage value calculated for the full design life".

## 3 Modification to Clause 2

*Replace Clause 2 with the following:* "

## 2 Basis of design

### 2.1 General

#### 2.1.1 Basic requirements

(1) P The aim of designing a structure against the limit state of fatigue is to ensure, with an acceptable level of probability, that its performance is satisfactory during its entire design life, such that the structure shall not fail by fatigue nor shall it be likely to require undue repair of damage caused by fatigue during the design life. The design of aluminium structures against the limit state of fatigue may be based on one of following methods:

a) safe life design (SLD) (see 2.2.1);

b) damage tolerant design (DTD) (see 2.2.2).



Either of methods a) and b) may be supplemented or replaced by design assisted by testing (see 2.2.3).

NOTE The national annex may specify conditions for the application for the above methods of design.

(2) The method for design against fatigue should be selected taking the use of the structure into account, considering the consequence class fixed for the components of the structure. In particular the accessibility for inspection of components and details where fatigue cracks are likely to occur should be considered.

(3) Fatigue assessment of components and structures should be considered in cases where the loads are frequently changing, particularly if reversing. Common situations where this may occur are e.g.:

— members supporting lifting appliances or rolling loads;

— members subjected to repeated stress cycles from vibrating machinery;

— members subjected to wind-induced oscillations;

— members subject to crowd-induced oscillations;

— moving structures (structures subject to inertia forces);

— members subjected to fluid flow induced oscillations or wave action.

NOTE The rules for fatigue resistance given in this standard apply generally to high cycle fatigue. For low cycle fatigue, guidelines are given in Annex F.

(4) The design rules in the other parts of EN 1999 apply.

## 2.2 Procedures for fatigue design

### 2.2.1 Safe life design (SLD)

(1) The safe life design method is based on the calculation of damage accumulation during the structure's design life or comparing the maximum stress range with the constant amplitude limit, using standard lower bound endurance data and an upper bound estimate of the fatigue loading, all based on design values. The approach provides a conservative estimate of the fatigue strength and does not normally depend on in-service inspection for fatigue damage.

NOTE Options considering in-service inspection are given in L1.

(2) The fatigue design involves prediction of the stress histories at potential crack initiation sites, followed by counting of load cycles with the associated stress ranges and compilation of stress spectra. From this information an estimate of the design life is made using the appropriate stress range endurance data for the constructional detail concerned. This method is given in A.2.

(3) The safe life design method may be based on one of two procedures to ensure sufficient resistance of the component or structure. The procedures are respectively based on that

a) the linear damage accumulation calculation is used, see (4);

b) the equivalent stress range approach is used, see (5)

NOTE A third procedure, for the case where all design stress ranges are less than the design constant amplitude fatigue limit, is given in L.1(4).



(4) For safe life design based on the assumption of linear damage accumulation (Palmgren-Miner's summation) the damage value $D_L$ for all cycles should fulfill the condition:

$$D_{L,d} \leq 1 \quad (2.1\ a)$$



where

$D_{L,d} = \Sigma n_i / N_i$ is calculated in accordance with the procedure given in A.2.

or

$$D_L \leq D_{lim} \quad (2.1\ b)$$

where:

$D_L = \Sigma n_i / N_i$ is calculated in accordance with the procedure given in A.2 with $\gamma_{Mf} = \gamma_{Ff} = 1{,}0$.

NOTE The national annex may specify values for $D_{lim}$, see L.4. Recommended values of $D_{lim}$ are given in L.4 for use when resistance data in Annex J is adopted.

(5) In case the design is based on the equivalent stress range approach ($\Delta\sigma_{E,2e}$) the following condition should be fulfilled:

$$\frac{\gamma_{Ff}\Delta\sigma_{E,2e}}{\Delta\sigma_C / \gamma_{Mf}} \leq 1 \quad (2.2)$$

NOTE Recommended values for $\gamma_{Mf}$ are given in L.4. For $\gamma_{Ff}$, see 2.4.

### 2.2.2 Damage tolerant design (DTD)

(1) P A damage tolerant design requires that a prescribed inspection and maintenance programme for detecting and correcting any fatigue damage is prepared and followed throughout the design life of the

structure. It should provide an acceptable reliability that a structure will perform satisfactorily for its design life. Prerequisites for use of this method and determination of an inspection strategy are given in A.3.

NOTE 1 Damage tolerant design may be suitable for application where a safe life assessment shows that fatigue has a significant effect on design economy and where a higher risk of fatigue cracking during the design life may be justified than is permitted using safe life design principles. The approach is intended to result in the same reliability level as obtained by using the approach of safe life design.

NOTE 2 Damage tolerant design may be applied in two different types of approach, DTD-I and DTD-II, see Annex L.

(2) The following guidelines should be considered for the structural layout and detailing:

— select details, material 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;

— choose wherever possible a structural concept where in the event of fatigue damage a redistribution of load effects within the structure or within the cross section of a member can occur (principle of redundancy);

— provide crack-arresting details;

— assure that critical components and details are readily inspectable during regular inspection;

— ensure that cracks can be kept under control by monitoring or, if needed, that components are readily repairable or replaceable.



### 2.2.3 Design assisted by testing

(1) This approach should be used where the necessary loading data, response data, fatigue strength data or crack growth data are not available from standards or other sources for a particular application, and for optimisation of constructional details. Test data should only be used in lieu of standard data on condition that they are obtained and applied under controlled conditions.



NOTE Verification of design by testing should be carried out in accordance with Annex C.

## 2.3 Fatigue loading

### 2.3.1 Sources of fatigue loading

(1) P All sources of fluctuating stress in the structure should be identified. Common fatigue loading situations are given in 2.1.1.

NOTE For limitation of fatigue induced by repeated local buckling, see D.3.

(2) The fatigue load should be obtained from EN 1991 or other relevant European Standard.

NOTE The national annex may give rules for the determination of the fatigue loads for cases not covered by a European Standard.

(3) Dynamic effects should be taken into account unless already allowed for in the fatigue load effects.

### 2.3.2 Derivation of fatigue loading

(1) In addition to the fatigue load standards the following clauses should be considered:

(2) Load for fatigue should normally be described in terms of a design load spectrum, which defines a range of intensities of a specific live load event and the number of times that each intensity level is applied during the structure's design life. If two or more independent live load events are likely to occur then it will be necessary to specify the phasing between them.

(3) Realistic assessment of the fatigue load is crucial to the calculation of the life of the structure. Where no published data for live load exist, resort should be made to obtaining data from existing structures subjected to similar effects.

(4) By recording continuous strain or deflection measurements over a suitable sampling period, load data should be inferred by subsequent analysis of the response. Particular care should be taken to assess dynamic magnification effects where load frequencies are close to one of the natural frequencies of the structure.

NOTE Further guidance is given in Annex C.

(5) The design load spectrum should be selected on the basis that it is an upper bound estimate of the accumulated service conditions over the full design life of the structure. Account should be taken of all likely operational and exposure condition effects arising from the foreseeable usage of the structure during that period.

(6) The confidence limit to be used for the intensity of the design load spectrum should be based on the mean predicted value plus $k_F$ standard deviations. The confidence limit to be used for the number of cycles in the design load spectrum should be based on the mean predicted value plus $k_N$ standard deviations.

NOTE Values of $k_F$ and $k_N$ may be defined in the national annex. The numerical values $k_F$ = 2, and $k_N$ = 2 are recommended. See also NOTE 2 under 2.4 (1).

### 2.3.3 Equivalent fatigue loading



(1) A simplified equivalent fatigue load may be used if the following conditions are satisfied:

a) the structure falls within the range of basic structural forms and size for which the equivalent fatigue load was originally derived;



b) the real fatigue load is of similar intensity and frequency and is applied in a similar way to that assumed in the derivation of the equivalent fatigue load;

c) the values of $m_1$, $m_2$, $N_D$ and $N_L$, see Figure 6.1, assumed in the derivation of equivalent fatigue load are the same as those appropriate to the constructional detail being assessed;

NOTE Some equivalent fatigue loads may have been derived assuming a simple continuous slope where $m_2 = m_1$ and $\Delta\sigma_L = 0$. For many applications involving numerous low amplitude cycles this will result in a very conservative estimate of life.

d) the dynamic response of the structure is sufficiently low that the resonant effects, which will be affected by differences in mass, stiffness and damping coefficient, will have little effect on the overall Miner summation.

(2) In the event that an equivalent fatigue load is derived specifically for an aluminium alloy structural application, all the matters addressed in (1) above should be taken into account.

## 2.4 Partial factors for fatigue loads

(1) Where the fatigue loads $F_{Ek}$ have been derived in accordance with the requirements of 2.3.1 (2) and 2.3.2 a partial factor should be applied to the loads to obtain the design load $F_{Ed}$.

$$F_{Ed} = \gamma_{Ff} F_{Ek} \tag{2.4}$$

where

$\gamma_{Ff}$ is the partial factor for fatigue loads.

NOTE 1 The partial factors may be defined in the national annex. A value of $\gamma_{Ff}$ = 1,0 is recommended.

NOTE 2 Where fatigue loads have been based on other confidence limits than those in 2.3.2 (6), recommended values for partial factors on loads are given in Table 2.1. Alternative values may be specified in the national annex.

**Table 2.1 — Recommended partial factors $\gamma_{Ff}$ for intensity and number of cycles in the fatigue load spectrum**

| $k_F$ | $\gamma_{Ff}$ | |
|---|---|---|
| | $k_N = 0$ | $k_N = 2$ |
| 0 | 1,5 | 1,4 |
| 1 | 1,3 | 1,2 |
| 2 | 1,1 | 1,0 |

### 2.5 Execution requirements

(1) EN 1090-3 requires execution classes to be selected. These may be related to service category.

NOTE Guidance on selection of execution class and service category is given in EN 1999-1-1. Guidance on utilization grade is given in L.5.".

## 4 Modification to 5.8.1 (2)

*Replace 5.8.1 (2) with the following:* "



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



## 5 Modification to 5.8.2 (1)

*Replace 5.8.2 (1) with the following:* "



(1) The design value of nominal stress ranges $\gamma_{Ff} \cdot \Delta\sigma_{E,2e}$ should be determined as follows:

$$\gamma_{Ff}\Delta\sigma_{E,2e} = \lambda_1 \times \lambda_2 \times \ldots \lambda_i \times \ldots \lambda_n \times \Delta\sigma(\gamma_{Ff} Q_k) \text{ for nominal stress} \qquad (5.1)$$

$$\gamma_{Ff}\Delta\sigma^*_{E,2e} = K_{gt}\,\gamma_{Ff}\Delta\sigma_{E,2e} \text{ for modified nominal stress} \qquad (5.2)$$

where

$\Delta\sigma(\gamma_{Ff}\,Q_k)$ is the stress range caused by the fatigue loads specified in EN 1991;

$\lambda_i$ are damage equivalent factors depending on the load situation and the structural characteristics as well as other factors;

$K_{gt}$ is the stress concentration factor to take account of the local stress magnification in relation to detail geometry not included in the reference $\Delta\sigma_C$-$N$-curve, see 5.3.2.1.

NOTE 1 The values of $\lambda_i$ may be given in the national annex.

NOTE 2 $\lambda_i$ –values for steel components may not be applicable for aluminium components.".

## 6 Modifications to 6.2.1 (2)

*In 6.2.1 (2), replace*

"$\Delta\sigma_i$ is the stress range for the principal stresses at the constructional detail and is constant for all cycles"