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Eurocode 9: Design of aluminium structures - Part 1-1: General structural rules

Eurocode 9: Bemessung und Konstruktion von Aluminiumtragwerken - Teil 1-1: Allgemeine Bemessungsregeln

Eurocode 9: Calcul des structures en aluminium - Partie 1-1: Règles générales

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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 1999-1-1:2007. 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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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This document (EN 1998-2:2005/prA1:2008) 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.

Draft Amendment to EN 1999-1-1: 2007

6.3.1.3 Slenderness for flexural buckling

(1) The relative slenderness $\overline{\lambda}$ is given by:

$$\overline{\lambda} = \sqrt{\frac{A_{\text{eff}}\, f_{\text{o}}}{N_{\text{cr}}}} = \frac{L_{\text{cr}}}{i}\,\frac{1}{\pi}\sqrt{\frac{A_{\text{eff}}}{A}\,\frac{f_{\text{o}}}{E}} \qquad (6.52)$$

where:

L_{cr} is the buckling length in the buckling plane considered

i is the radius of gyration about the relevant axis, determined using the properties of gross cross-section.

(2) The buckling length L_{cr} should be taken as *kL*, where *L* is the length between points of lateral support; for a cantilever, *L* is its length. The value of *k*, the buckling length factor for members, should be assessed from knowledge of the end conditions. Unless more accurate analysis is carried out, Table 6.8 should be used.

NOTE The buckling length factors *k* are increased compared to the theoretical value for fixed ends to allow for various deformations in the connection between different structural parts.

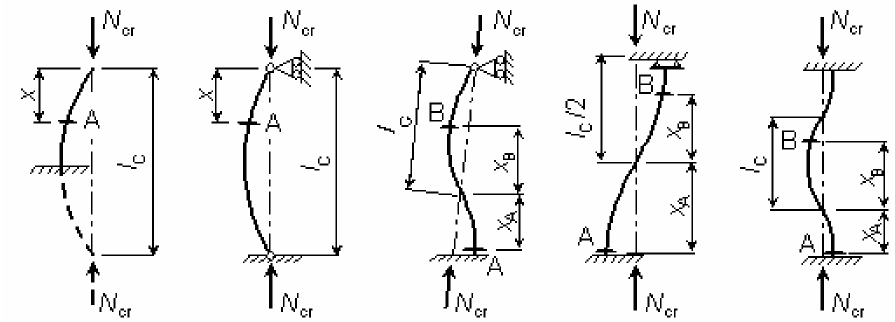
Table 6.8 - Buckling length factor *k* for members

End conditions	*k*
1. Held in position and restrained in direction at both ends	0,7
2. Held in position at both ends and restrained in direction at one end	0,85
3. Held in position at both ends, but not restrained in direction	1,0
4. Held in position at one end, and restrained in direction at both ends	1,25
5. Held in position and restrained in direction at one end, and partially restrained in direction but not held in position at the other end	1,5
6. Held in position and restrained in direction at one end, but not held in position or restrained at the other end	2,1

6.3.3.5 Unequal end moments and/or transverse loads

(2) For end moments $M_{\text{Ed,1}} > M_{\text{Ed,2}}$ only, the distance x_{s} can be calculated from

$$\cos\left(\frac{x_{\text{s}}\pi}{l_c}\right) = \frac{(M_{\text{Ed,1}} - M_{\text{Ed,2}})}{M_{\text{Rd}}} \cdot \frac{N_{\text{Rd}}}{N_{\text{Ed}}} \cdot \frac{1}{\pi(1/\chi - 1)} \quad \text{but } x_{\text{s}} \geq 0 \qquad (6.71)$$



A and B are examples of studied sections marked with transverse lines. See Table 6.8 for value of buckling length $l_{\text{c}} = KL$.

Figure 6.14 - Buckling length l_{c} and definition of x_{s} $(= x_A \text{ or } x_B)$

8.3 Joints loaded in shear subject to impact, vibration and/or load reversal

(1) Where a joint loaded in shear is subject to frequent impact or significant vibration either welding, preloaded bolts, injection bolts or other types of bolts, which effectively prevent movement and loosening of fastener, should be used.

(2) Where slipping is not acceptable in a joint because it is subject to reversal of shear load (or for any other reason), preloaded bolts in a slip-resistant connection (category B or C as appropriate, see 8.5.3), fitted bolts or welding should be used.

(3) For wind and/or stability bracings, bolts in bearing type connections (category A in 8.5.3) should be used.

8.5.1 Positioning of holes for bolts and rivet

(12) Oversized holes in bolted connections of Category A may be used if the following conditions are met:

- a possible greater setting of the structure or of the component can be accepted;
- no reversal loads are acting;
- oversized bolts holes are used on one side of a joint, where they should be applied in the component to be connected or in the connecting devices (cover plates, gussets);
- the rules for geometrical tolerances for oversized holes given in EN 1090-3 are applied;
- for bolts with diameter $d \leq 10$ mm the design resistance of the bolt group based on bearing is less than the design resistance of the bolt group based on shear. See also 8.5.5 (7).

8.5.5 Design resistances of bolts

(7) The values for design shear resistance $F_{v,Rd}$ given in Table 8.5 apply only where the bolts are used in holes with nominal clearances not exceeding those for standard holes as specified in EN 1090-3. For oversized holes and slotted holes $F_{v,RD}$ is redused by a factor of 0,7.

8.5.14 Pin connections

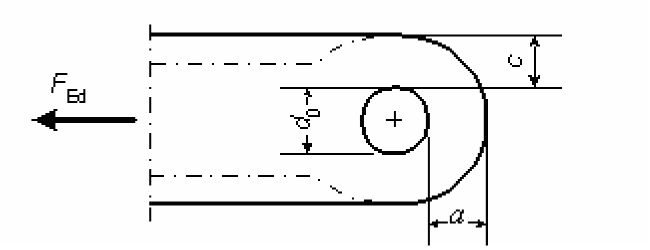
8.5.14.1 General

(1) Pin connections where rotation is required should be designed according to 8.5.14.2 – 8.5.14.3.

(2) Pin connections in which no rotation is required may be designed as single bolted connections, provided that the length of the pin is less than 3 times the diameter of the pin, see 8.5.3. For all other cases the method in 8.5.14.3 should be followed.

8.5.14.2 Pin holes and pin plates

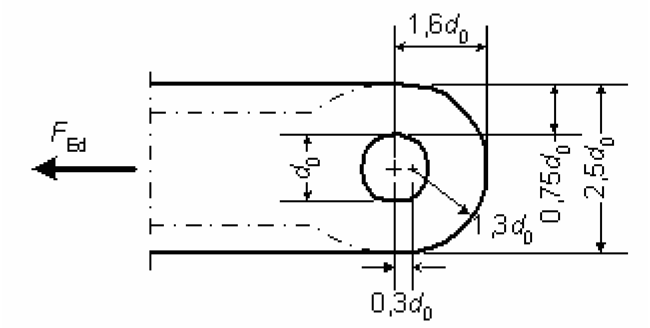
(1) The geometry of plates in pin connections should be in accordance with the dimensional requirements, see Figure 8.12.



$$a \geq \frac{F_{Ed}\gamma_{M1}}{2tf_o} + \frac{2d_0}{3}$$

$$c \geq \frac{F_{Ed}\gamma_{M1}}{2tf_o} + \frac{d_0}{3}$$

a) Given thickness and diameter of hole



$$t \geq 0{,}7\sqrt{\frac{F_{\mathrm{Ed}}\gamma_{\mathrm{M1}}}{f_{\mathrm{o}}}}$$

$$d_0 \geq 1{,}75\sqrt{\frac{F_{\mathrm{Ed}}\gamma_{\mathrm{M1}}}{f_{\mathrm{o}}}}$$

t = thickness of member (plate)
d_0 = diameter of hole

b) Given geometry

Figure 8.12 - Geometrical requirements for pin ended members

(2)P At the ultimate limit state the design force F_{Ed} in the plate shall not exceed the design resistance given in Table 8.7.

(3) Pin plates provided to increase the net area of a member or to increase the bearing resistance of a pin should be of sufficient size to transfer the design force from the pin into the member and should be arranged to avoid eccentricity.

8.5.14.3 Design of pins

(1) Pins should not be loaded in single shear, so one of the members to be joined should have a fork end, or clevis. The pin retaining system, e.g. spring clip, should be designed to withstand a lateral load not less than 10% of the total shear load of the pin.

(2) The bending moments in a pin should be calculated as indicated in Figure 8.13.

(3) At the ultimate limit state the design forces and moments in a pin should not exceed the relevant design resistances given in Table 8.7.

(4) If the pin is intended to be replaceable (multiple assembling and disassembling of a structure), in addition the provisions given in 8.5.14.2 and 8.5.14.3 the contact bearing stress should satisfy:

$$\sigma_{\mathrm{h,Ed}} \leq f_{\mathrm{h,Rd}} \tag{8.28a}$$

where

$$\sigma_{\mathrm{h,Ed}} = 0{,}591\sqrt{\frac{F_{\mathrm{Ed,ser}}(d_0 - d)}{d^2 t}}\sqrt{\frac{2E_{\mathrm{p}}E_{\mathrm{pl}}}{E_{\mathrm{p}} + E_{\mathrm{pl}}}} \tag{8.28b}$$

$f_{\mathrm{h,Rd}} = 2{,}5\, f_{\mathrm{o}}/\gamma_{\mathrm{M6,ser}}$

where:

d	is the diameter of the pin
d_0	is the diameter of the pin hole
$F_{\mathrm{Ed,ser}}$	is the design value of the force to be transferred in bearing under the characteristic load combination for serviceability limit state
E_{p}, E_{pl}	is the elastic modulus of the pin and the plate material respectively.

Table 8.7 - Design resistances for pin connections

Criterion	Resistance	
Shear of the pin If the pin is intended to be replaceable this requirement should also be satisfied	$F_{v,Rd} = 0{,}6\, A\, f_{up}/\gamma_{Mp}$ $F_{v,Rd,\,ser} = 0{,}6\, A\, f_{op}/\gamma_{M6,ser}$	$\geq F_{v,Ed}$ $\geq F_{v,Ed,ser}$
Bearing of the plate and the pin If the pin is intended to be replaceable this requirement should also be satisfied	$F_{b,Rd} = 1{,}5\, t\, d\, f_{o,min}/\gamma_{M1}$ $F_{b,Rd} = 0{,}6\, t\, d\, f_o/\gamma_{M6,ser}$	$\geq F_{b,Ed}$ $\geq F_{b,Ed,ser}$
Bending of the pin If the pin is intended to be replaceable this requirement should also be satisfied	$M_{Rd} = 1{,}5\, W_{el}\, f_{op}/\gamma_{M1}$ $M_{Rd} = 0{,}8\, W_{el}\, f_{op}/\gamma_{M6,ser}$	$\geq M_{Rd}$ $\geq M_{Ed,ser}$
Combined shear and bending of the pin	$(M_{Ed}/M_{Rd})^2 + (F_{v,Ed}/F_{v,Rd})^2 \leq 1{,}0$	

d	is the diameter of the pin
$f_{o,min}$	is the lower of the design strengths of the pin and the connected part
f_{up}	is the ultimate tensile strength of the pin
f_{op}	is the yield strength of the pin
t	is the thickness of the connected part
A	is the cross sectional area of a pin.

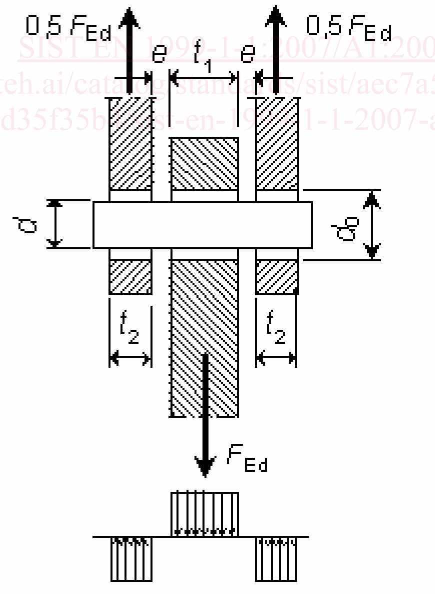


Figure 8.13 - Actions and action effects on a pin

$$M_{Ed} = F_{Ed}(2t_2 + 4e + t_1)/8 \tag{8.28c}$$

8.6.3.3 Design of fillet welds

(4) If the length of the weld is less than 8 times the throat thickness the resistance of the weld should not be taken into account. If the stress distribution along the length of the weld is not constant, see Figure 8.16b, and the length of the weld exceeds 100 times the throat thickness the effective weld length of longitudinal welds should be taken as:

$$L_{w,eff} = (1{,}2 - 0{,}2\, L_w/100\, a)\, L_w \quad \text{with} \quad L_w \geq 100\, a \qquad (8.32)$$

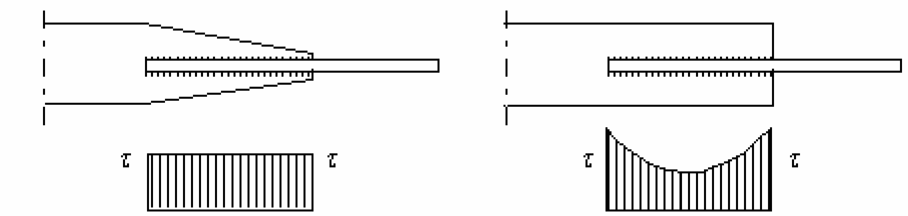
where:

$L_{w,eff}$ = effective length of longitudinal fillet welds

L_w = total length longitudinal fillet welds

a = effective throat thickness, see Figure 8.17.

NOTE With non-uniform stress distributions and thin, long welds the deformation capacity at the ends may be exhausted before the middle part of the weld yields; thus the connection fails by a kind of zipper-effect.



a) Example of a uniform stress distribution **b) Example of a non uniform stress distribution**

Figure 8.16 - Stress Distributions in Joints with Fillet Welds

Annex A [informative] – Reliability differentiation

A.1 Introduction

(1) EN 1990 gives in its section 2 basic requirements to ensure that the structure achieves the required reliability. Its Annex B introduces consequence classes and reliability classes and gives guidelines for the choice of consequence class for the purpose of reliability differentiation. Consequence classes for structural components are divided in three levels noted CCi (i = 1, 2 or 3)

(2) The consequence class and the associated reliability class for a structure or component have implications for the requirements for the design and execution of the structure, and in particular to requirements to design supervision and to inspection of execution.

(3) This annex is a guide for the application of the various parts of EN 1999 and for drafting the execution specification required by EN 1090-3.

A.2 Design provisions for reliability differentiation - Design supervision levels

(1) The guidance in EN 1990, Annex B for reliability differentiation provides:

- rules for design supervision and checking of structural documentation, expressed by Design Supervision Levels;
- rules for determination of design actions and combination of actions, expressed by the partial factors for actions.

NOTE The National Annex may give rules for the application of consequence classes and reliability classes and for the connection between them and requirements for design supervision. Recommendations are given in EN 1990 Annex B.

A.3 Execution provisions for reliability differentiation – Execution classes

(1) Execution classes are introduced in order to differentiate in requirements to structures and their components for reliability management of the execution work, in accordance with EN 1990, clause 2.2 and its informative Annex B.

(2) Aluminium structures are classified in 4 execution classes denoted EXC1, 2, 3 and 4, where class 4 has the most stringent requirements.

NOTE EN 1990 recommends three consequence classes and three reliability classes. EN 1990 does, however, not include structures subject to fatigue that is covered in EN 1999-1-3.

(3) The execution class may apply to the whole structure, to a part of a structure, to one or more components or to specific details. A structure may include more than one execution class.

(4) It is a condition that the execution of structures and structural components is undertaken according to EN 1090-3 following the rules for the various execution classes given in EN 1090-3.

A.4 Governing factors for choice of execution class

(1) The execution class should be selected based on the following three conditions:

a. the consequences of a structural failure, either human, economical or environmental;

b. the type of loading, i.e. whether the structure is subject to predominantly static loading or a significant fatigue loading;

c. the technology and procedures to be used for the work connected with the requirements for the quality level of the component.

(2) For considerations of the conditions under (a.) by use of consequence classes, see A.1.