The Second Generation Eurocodes

Key changes and benefits through design examples

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EN 1999 ‘Eurocode 9: Design of aluminium structures- Part 1-1: General rules’

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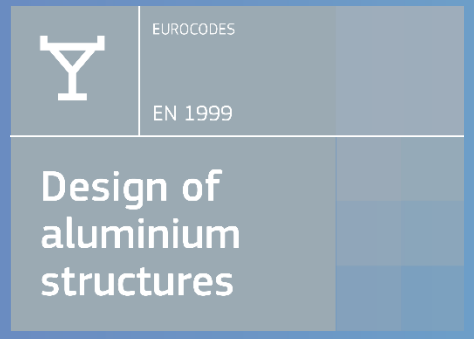
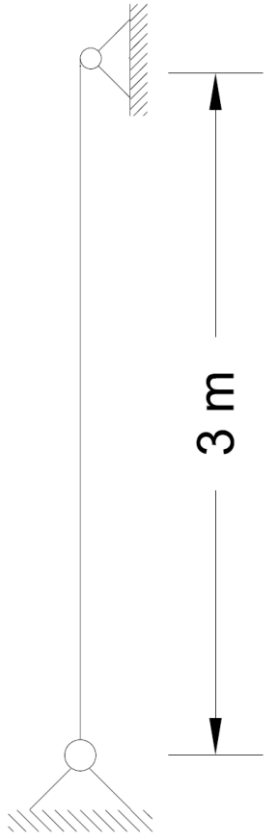


Buckling resistance

- Aluminium column



h=3.0m

P=30 kN

Circular hollow section 89 x 4.7 *(HSS Hydro)*

EN AW 6082-T4

Material

- EN AW 6082-T4/ Buckling Class C

Alloy EN AW	Product form	Temper	Thick-ness, t, mm[a, c]	f_o[a]	f_u[a]	A[e, b]	$f_{o,haz}$[d]	$f_{u,haz}$[d]	HAZ-factor[d]		BC[f]	n_p[g]
				N/mm²		%	N/mm²		$\rho_{o,haz}$	$\rho_{u,haz}$		
6082	EP, ET, ER/B	T4	$t \leq 25$	110	205	14	100	160	0,91	0,78	C	8
	EP	T5	$t \leq 5$	230	270	8	125	185	0,54	0,69	A	28
	EP, ET	T6	$t \leq 5$	250	290	8	125	185	0,50	0,64	A	32
			$5 < t \leq 15$	260	310	10			0,48	0,60	A	25
	ER/B	T6	$t \leq 20$	250	295	8			0,50	0,63	A	27
			$20 < t \leq 150$	260	310	8			0,48	0,60	A	25
	DT	T6	$t \leq 5$	255	310	8			0,49	0,60	A	22
			$5 < t \leq 20$	240	310	10			0,52	0,60	B	17

EN1999-1-1: 2023/ Table 5.4

$$\varepsilon = \sqrt{\frac{250}{110}} \Rightarrow \varepsilon = 1.5$$

Local buckling-Classification

$$\beta = k_0 \times \sqrt{\frac{D_m}{t}} = 6 \times \sqrt{\frac{89 - 4.7}{84.7}} = 25.41$$

k_0 = 3 (tube in bending)

k_0 = 6 (uniform compression)

D_m diameter to mid-thickness of the round tube

Slenderness limits

$$\beta_3 = 22 \times \varepsilon = 22 \times 1.5 = 33.16$$

$$\beta_2 = 16 \times \varepsilon = 16 \times 1.5 = 24$$

$$\beta = 25.41 < \beta_3$$

Slenderness parameters

	Buckling Class according to Table 5.3 and Table 5.4	Internal part		Outstand part	
		β_2/ε	β_3/ε	β_2/ε	β_3/ε
Without welds	A	16	22	4,5	6
	B	16	20	4,5	5,5
	C	16	18	4,5	5
With welds	A	13	18	4,0	5
	B	13	16,5	3,8	4,5
	C	13	15	3,5	4
[a] with for (a): $\varepsilon = \sqrt{\frac{250}{f_o}}$ with f_o in MPa					

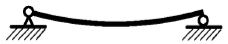
Section-Profile/Class 3

EN1999-1-1: 2023/ Table 8.1

Buckling length

$L_{cr} = k \times L$

- *L :* member length
- The value of *k*, the buckling length factor for members= f (the end conditions).

End conditions		k
1. Rotation: clamped – clamped; displacement: fixed – fixed		0,7
2. Rotation: clamped – hinge; displacement: fixed – fixed		0,85
3. Rotation: hinge – hinge; displacement: fixed – fixed (not relevant)		1,0
4. Rotation: clamped – clamped; displacement: fixed – free		1,25
5. Rotation: clamped – partially restrained; displacement: fixed – free		1,5
6. Rotation: clamped – free; displacement: fixed – free (cantilever)		2,1
7. Rotation: hinge – elastically clamped; displacement: fixed – free		≧2,1[a]
[a] Depends on stiffness at the clamped end.		

EN1999-1-1: 2023/ Table 8.7

$$l_{cr} = k \times l = 1 \times 3.00 = 3.0m$$

Buckling load/ relative slenderness

- Elastic critical force for the relevant buckling mode

$$\mathrm{N}_{cr} = \frac{\pi^2 \times \mathrm{E} \times \mathrm{I}}{l_{cr}^2} = \frac{\pi^2 \times 70000 \times \mathrm{I}}{l_{cr}^2} = \frac{\pi^2 \times 70000 \times 1.11 \times 10^6}{3000^2} \Rightarrow \mathrm{N}_{cr} = 85.207kN$$

- Relative slenderness

$$\overline{\lambda} = \sqrt{\frac{A_{eff} \times f_0}{N_{cr}}} = \sqrt{\frac{1254 \times 110}{85207}} = 1.272$$

A=1254 mm^2

I= 1.11 x 10 mm^4

Reduction factor

$$\varphi = 0.5 \times [1 + \alpha \times (\bar{\lambda} - \overline{\lambda_0}) + \overline{\lambda^2}]$$

$$\varphi = 0.5 \times [1 + 0.56 \times (1.272 - 0.14) + 1.2722]$$

$$\varphi = 1.626$$

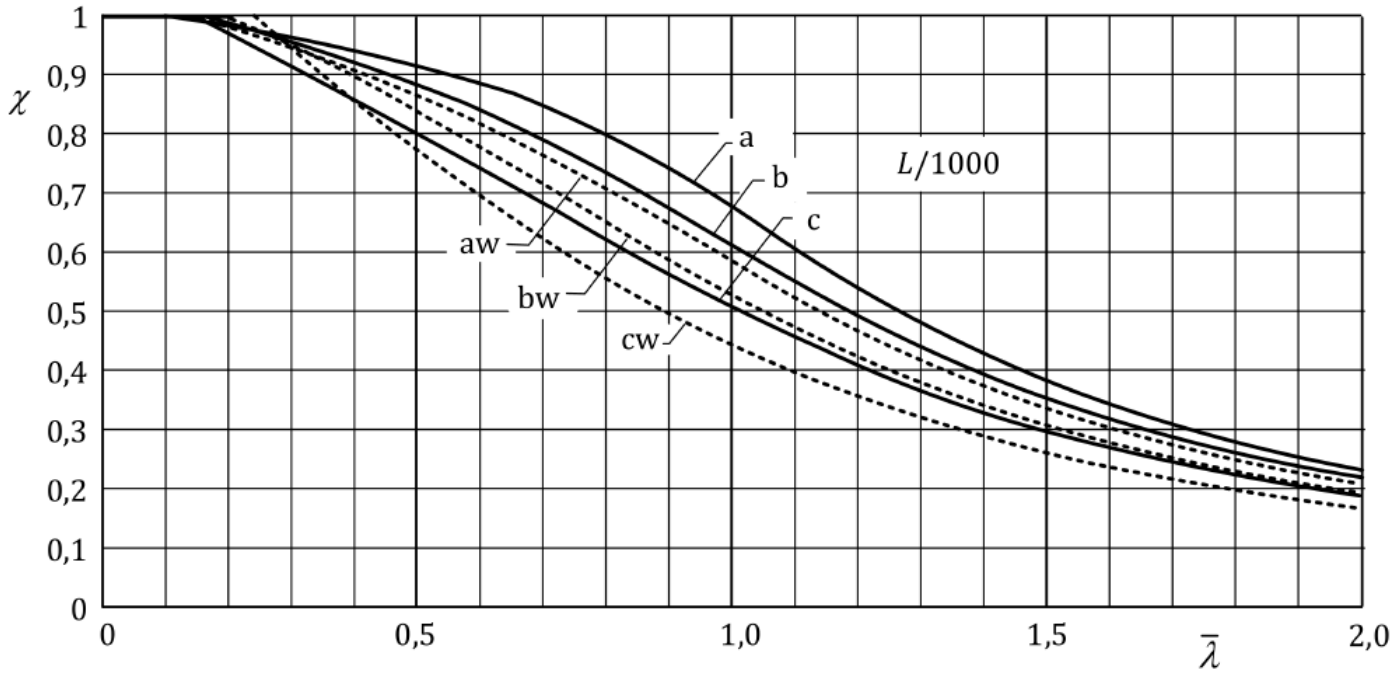
a, λ_0 (flexural buckling)

	Buckling class BC according to Table 5.3 and Table 5.4	Curve	α	$\bar{\lambda}_0$
Without weld	A	a	0,18	0,10
	B	b	0,30	0,15
	C	c	0,56	0,14
Longitudinal weld	A	aw	0,36	0,16
	B	bw	0,54	0,22
	C	cw	0,92	0,24

EN1999-1-1:2023/ Table 8.5

Buckling curves

- Imperfection factor α,
- Length Horizontal plateau of the buckling curves $\bar{\lambda}_0$, corresponding to the appropriate buckling curves

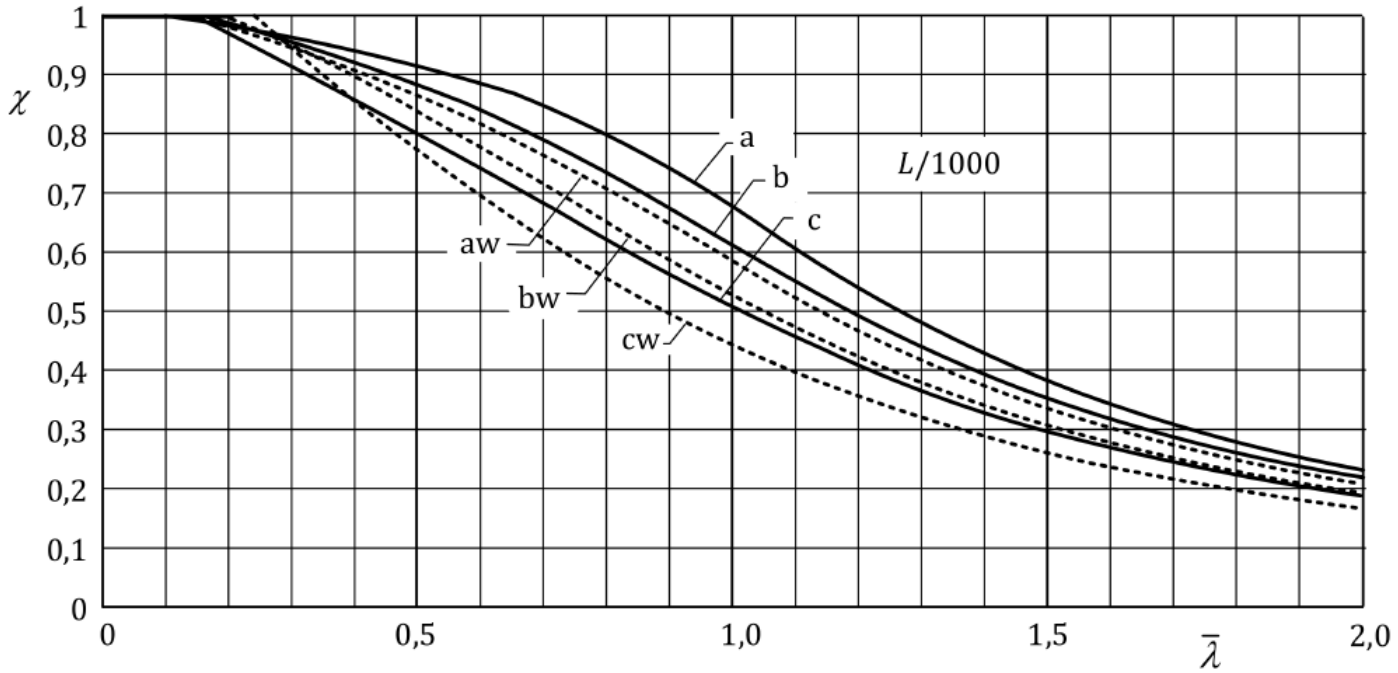


EN1999-1-1:2023/ Fig. 8.10

Reduction factor

Values of the reduction factor, χ, for the appropriate relative slenderness, $\bar{\lambda}$

Reduction factor for flexural buckling



EN1999-1-1:2023/ Fig. 8.10

Reduction factor-Buckling resistance

- **Reduction factor**

$$\chi = \frac{1}{\varphi + \sqrt{\varphi^2 - \bar{\lambda}^2}} \Rightarrow \qquad \chi = \frac{1}{1.626 + \sqrt{1.626^2 - 1.272}} = 0.372$$

- **Buckling resistance** *EN1999-1-1: 2009*

$$\mathrm{N}_{b.\mathrm{Rd}} = \frac{\kappa \times \chi \times \mathrm{A}_{\mathrm{eff}} \times \mathrm{f}_0}{\gamma_{M1}} = \frac{1 \times 0.372 \times 1254 \times 110}{1.1} = 46.648\ kN$$

Calculation provisions

$$N_{b.Rd} = \frac{\chi \times A_{eff} \times f_0}{\omega_\chi \times \gamma_{M1}}$$

$$N_{b.Rd} = \frac{\chi_{haz} \times A_{u,eff} \times f_u}{\omega_{\chi,haz} \times \gamma_{M2}}$$

χ reduction factor for the relevant buckling mode

χ_{haz} reduction factor based on $\bar{\lambda}_{haz}$ (8.3.3.4(3).

For $\bar{\lambda}_{haz}$ buckling curve a, b or c should be used

EN1999-1-1:2023/ 8.3.1.2

Effective areas

A_{eff} Effective area/ local buckling and HAZ softening due to longitudinal welds.

Provisions for torsional and torsional-flexural buckling

For class 1, 2 and 3 cross-sections without longitudinal welds, $A_{eff} = A_g$

$A_{u,eff}$ Effective area taking into account local buckling and HAZ softening

- General yielding along the member: $N_{o,Rd} = A_{eff} \times f_o/\gamma_{M1}$ *(EN1999-1-1:2023/ 8.24)*
- Failure at a local reduction cross-section: $N_{net,Rd} = A_{net} \times f_u/\gamma_{M2}$ *(EN1999-1-1:2023/ 8.25)*
- Failure at a section with transverse weld: $N_{u,Rd} = A_{u,eff} \times f_u/\gamma_{M2}$

Factor ω

ω_x factor taking into account the location of the design section along the member. *If there is axial force only then* $\omega_x = 1$

$\omega_{x,haz}$ factor taking into account the location of a localised weld along the member *(EN1999-1-1: 2023/ 8.3.3.4).*

Calculation provisions

$$N_{b.Rd} = \frac{\chi \times A_{eff} \times f_0}{\omega_\chi \times \gamma_{M1}}$$

$\omega_x = 1$

$$N_{b.Rd} = \frac{0.372 \times 1254 \times 110}{1 \times 1.1} = 46.648\ kN$$

EN1999-1-1:2023/ 8.3.1.2

Localized welds

$$N_{b.Rd} = \frac{\chi_{haz} \times A_{u,eff} \times f_u}{\omega_{\chi,haz} \times \gamma_{M2}}$$

$$\rho_{u,haz} = 0.78$$

$$A_{u,eff} = \rho_{u,haz} \times A$$

Alloy EN AW	Product form	Temper	Thick-ness, t, mm[a, c]	f_o[a]	f_u[a]	A[e, b]	$f_{o,haz}$[d]	$f_{u,haz}$[d]	HAZ-factor[d]		BC[f]	n_p[g]
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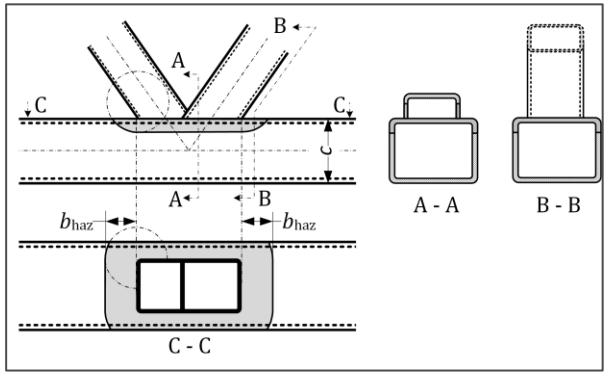
EN1999-1-1: 2023/ Table 5.4

EN1999-1-1: 2023/ 8.3.3.4



Thank you!