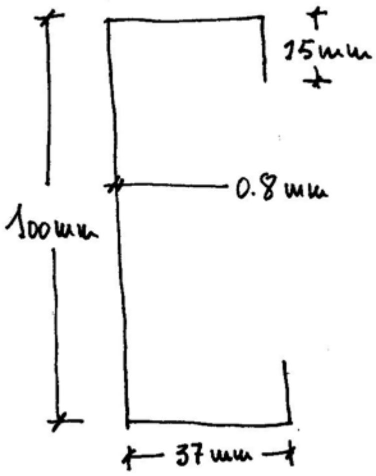
SECCION EFICAZ A COMPRESIÓN (obtención)

(1)



• 1ª vuelta con tensión $\sigma_{com,ED} = f_{yb} = 235 N/mm^2$

$(f_{ub} = 360 N/mm^2)$

5.5.3.2 Plane elements with edge stiffeners

(1) The following procedure is applicable to an edge stiffener if the requirements in 5.2 are met and the angle between the stiffener and the plane element is between 45° and 135°.

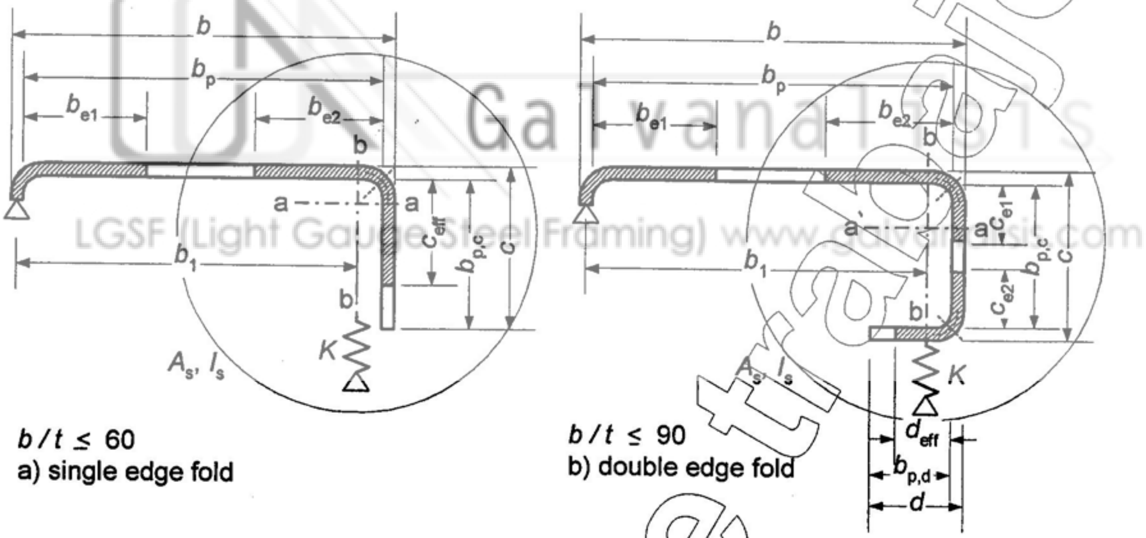


Figure 5.7: Edge stiffeners

(2) The cross-section of an edge stiffener should be taken as comprising the effective portions of the stiffener, element c or elements c and d as shown in figure 5.7, plus the adjacent effective portion of the plane element b_p.

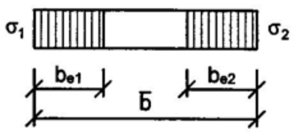
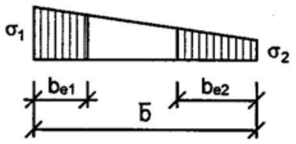
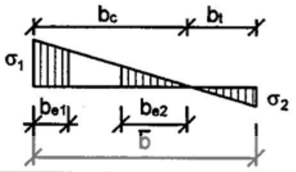
(3) The procedure, which is illustrated in figure 5.8, should be carried out in steps as follows:

- **Step 1**: Obtain an initial effective cross-section for the stiffener using effective widths determined by assuming that the stiffener gives full restraint and that $\sigma_{com,Ed} = f_{yb}/\gamma_{M0}$, see (4) to (5);
- **Step 2**: Use the initial effective cross-section of the stiffener to determine the reduction factor for distortional buckling (flexural buckling of a stiffener), allowing for the effects of the continuous spring restraint, see (6), (7) and (8);
- **Step 3**: Optionally iterate to refine the value of the reduction factor for buckling of the stiffener, see (9) and (10).

(4) Initial values of the effective widths b_{e1} and b_{e2} shown in figure 5.7 should be determined from clause 5.5.2 by assuming that the plane element b_p is doubly supported, see table 4.1 in EN 1993-1-5

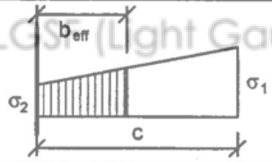
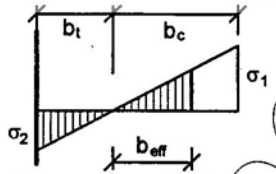
(continua en pag. 4)

Table 4.1: Internal compression elements

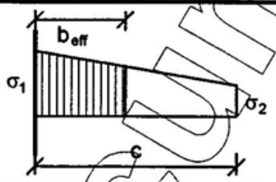
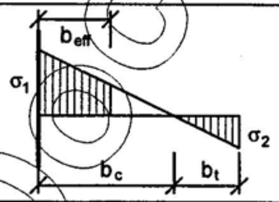
Stress distribution (compression positive)	Effective^p width b_{eff}
	$\underline{\psi = 1}$: $b_{eff} = \rho\ \bar{b}$ $b_{e1} = 0{,}5\ b_{eff}$ $\quad b_{e2} = 0{,}5\ b_{eff}$
	$\underline{1 > \psi \geq 0}$: $b_{eff} = \rho\ \bar{b}$ $b_{e1} = \dfrac{2}{5-\psi} b_{eff}$ $\quad b_{e2} = b_{eff} - b_{e1}$
	$\underline{\psi < 0}$: $b_{eff} = \rho\ b_c = \rho\ \bar{b} / (1-\psi)$ $b_{e1} = 0{,}4\ b_{eff}$ $\quad b_{e2} = 0{,}6\ b_{eff}$

$\psi = \sigma_2/\sigma_1$	1	$1 > \psi > 0$	0	$0 > \psi > -1$	-1	$-1 > \psi > -3$
Buckling factor k_σ	4,0	$8{,}2 / (1{,}05 + \psi)$	7,81	$7{,}81 - 6{,}29\psi + 9{,}78\psi^2$	23,9	$5{,}98\ (1 - \psi)^2$

Table 4.2: Outstand compression elements

Stress distribution (compression positive)	Effective^p width b_{eff}
	$\underline{1 > \psi \geq 0}$: $b_{eff} = \rho\ c$
	$\underline{\psi < 0}$: $b_{eff} = \rho\ b_c = \rho\ c / (1-\psi)$

$\psi = \sigma_2/\sigma_1$	1	0	-1	$1 \geq \psi \geq -3$
Buckling factor k_σ	0,43	0,57	0,85	$0{,}57 - 0{,}21\psi + 0{,}07\psi^2$

Stress distribution (compression positive)	Effective^p width b_{eff}
	$\underline{1 > \psi \geq 0}$: $b_{eff} = \rho\ c$
	$\underline{\psi < 0}$: $b_{eff} = \rho\ b_c = \rho\ c / (1-\psi)$

$\psi = \sigma_2/\sigma_1$	1	$1 > \psi > 0$	0	$0 > \psi > -1$	-1
Buckling factor k_σ	0,43	$0{,}578 / (\psi + 0{,}34)$	1,70	$1{,}7 - 5\psi + 17{,}1\psi^2$	23,8

4.4 Plate elements without longitudinal stiffeners

(1) The effective^p areas of flat compression elements should be obtained using Table 4.1 for internal elements and Table 4.2 for outstand elements. The effective^p area of the compression zone of a plate with the gross cross-sectional area A_c should be obtained from:

$$A_{c,eff} = \rho\, A_c \tag{4.1}$$

where ρ is the reduction factor for plate buckling.

(2) The reduction factor ρ may be taken as follows:

- internal compression elements:

$$\rho = 1{,}0 \qquad \text{for } \overline{\lambda}_p \leq 0{,}673$$

$$\rho = \frac{\overline{\lambda}_p - 0{,}055\,(3+\psi)}{\overline{\lambda}_p^2} \leq 1{,}0 \qquad \text{for } \overline{\lambda}_p > 0{,}673 \text{ , where } (3+\psi) \geq 0 \tag{4.2}$$

- outstand compression elements:

$$\rho = 1{,}0 \qquad \text{for } \overline{\lambda}_p \leq 0{,}748$$

$$\rho = \frac{\overline{\lambda}_p - 0{,}188}{\overline{\lambda}_p^2} \leq 1{,}0 \qquad \text{for } \overline{\lambda}_p > 0{,}748 \tag{4.3}$$

where $\overline{\lambda}_p = \sqrt{\dfrac{f_y}{\sigma_{cr}}} = \dfrac{\overline{b}/t}{28{,}4\,\varepsilon\,\sqrt{k_\sigma}}$

ψ is the stress ratio determined in accordance with 4.4(3) and 4.4(4)

$\overline{b}$ is the appropriate width to be taken as follows (for definitions, see Table 5.2 of EN 1993-1-1)

- b_w for webs;
- b for internal flange elements (except RHS);
- $b - 3\,t$ for flanges of RHS;
- c for outstand flanges;
- h for equal-leg angles;
- h for unequal-leg angles;

k_σ is the buckling factor corresponding to the stress ratio ψ and boundary conditions. For long plates k_σ is given in Table 4.1 or Table 4.2 as appropriate;

t is the thickness;

σ_{cr} is the elastic critical plate buckling stress see equation (A.1) in Annex A.1(2) and Table 4.1 and Table 4.2;

$$\varepsilon = \sqrt{\frac{235}{f_y\,[N/mm^2]}}$$

(3) For flange elements of I-sections and box girders the stress ratio ψ used in Table 4.1 and Table 4.2 should be based on the properties of the gross cross-sectional area, due allowance being made for shear lag in

$$\bar{\lambda}_p = \frac{37/0.8}{28.4 \times 1 \times \sqrt{4}} = 0.8143 > 0.673 \rightarrow \rho = \frac{0.8143 - 0.055(3+1)}{0.8143^2} = 0.896 \quad (4.2)$$

$$\underline{\underline{b_{e1}}} = \underline{\underline{b_{e2}}} = \frac{37 \times 0.896}{2} = \underline{\underline{16.6\ mm}} \quad \text{(tabla 4.1)}$$

- cálculo del rigidizador.

cálculo del labio

(viene de la pag. 1)

prEN 1993-1-3 : 2006 (E)

(5) Initial values of the effective widths c_{eff} and d_{eff} shown in figure 5.9 should be obtained as follows:

a) for a single edge fold stiffener:

$c_{eff} = \rho\, b_{p,c}$ ... (5.13a)

with ρ obtained from 5.5.2, except using a value of the buckling factor k_σ given by the following:

- if $b_{p,c}/b_p \leq 0{,}35$:

$k_\sigma = 0{,}5$ ... (5.13b)

- if $0{,}35 < b_{p,c}/b_p \leq 0{,}6$:

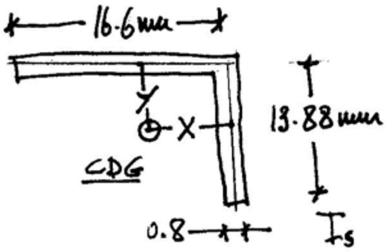
$k_\sigma = 0{,}5 + 0{,}83\sqrt[3]{(b_{p,c}/b_p - 0{,}35)^2}$ ...(5.13c)

$$\frac{b_{p,c}}{b_p} = \frac{15}{37} = 0.4054 > 0.35 \rightarrow K_\sigma = 0.5 + 0.83\sqrt[3]{\left(\frac{15}{37} - 0.35\right)^2} = 0.62 \quad \cdots (5.13c)$$

$$\bar{\lambda}_p = \frac{15/0.8}{28.4\sqrt{0.62}} = 0.838 > 0.748 \rightarrow \rho = \frac{0.838 - 0.188}{0.838^2} = 0.9256 \quad (4.3)$$

$$\underline{\underline{C_{eff}}} = 0.9256 \times 15 = \underline{\underline{13.88\ mm}}$$

- tensión crítica del rigidizador.



situación del centro de gravedad.

$$\underline{\underline{Y}} = \frac{13.88 \times \frac{13.88}{2}}{16.6 + 13.88} = \underline{\underline{3.16\ mm}}\ ; \quad \underline{\underline{X}} = \frac{16.6 \times \frac{16.6}{2}}{16.6 + 13.88} = \underline{\underline{4.52\ mm}}$$

$$I_s = \frac{16.6 \times 0.8^3}{12} + \frac{0.8 \times 13.88^3}{12} + 16.6 \times 0.8 \times 3.16^2 + 13.88 \times 0.8\left(\frac{13.88}{2} - 3.16\right)^2 = 470.24\ mm^4$$

(área del rigidizador) $\underline{A_s} = (16.6 + 13.88) \times 0.8 = \underline{\underline{24.38\ mm^2}}$

prEN 1993-1-3:2006; 5.5.3.1

5

(5) In the case of the edge stiffeners of lipped C-sections and lipped Z-sections, C_θ should be determined with the unit loads u applied as shown in figure 5.8(c). This results in the following expression for the spring stiffness K_1 for the flange 1:

$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2\, h_w + b_1^3 + 0{,}5\, b_1\, b_2\, h_w\, k_f} \quad \text{(ver páginas 14 y 15)} \quad \ldots (5.10b)$$

where:

- b_1 is the distance from the web-to-flange junction to the gravity center of the effective area of the edge stiffener (including effective part b_{e2} of the flange) of flange 1, see figure 5.8(a);
- b_2 is the distance from the web-to-flange junction to the gravity center of the effective area of the edge stiffener (including effective part of the flange) of flange 2;
- h_w is the web depth;
- $k_f = 0$ if flange 2 is in tension (e.g. for beam in bending about the y-y axis);
- $k_f = \dfrac{A_{eff2}}{A_{eff1}}$ if flange 2 is also in compression (e.g. for a beam in axial compression);
- $k_f = 1$ for a symmetric section in compression.

A_{eff1} and A_{eff2} is the effective area of the edge stiffener (including effective part b_{e2} of the flange, see figure 5.8(b)) of flange 1 and flange 2 respectively.

$$K_1 = \frac{210000 \times 0.8^3}{4(1-0.3^2)} \cdot \frac{1}{(37-4.52)^2 \times 100 + (37-4.52)^3 + 0.5\,(37-4.52)^2 \times 100} = 0.153 \quad \ldots (5.10b)$$

prEN 1993-1-3:2006; 5.5.3.2

(7) The elastic critical buckling stress $\sigma_{cr,s}$ for an edge stiffener should be obtained from:

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s} \quad \text{(tensión crítica de una barra sobre cimentación elástica)} \quad \ldots (5.15)$$

where:

- K is the spring stiffness per unit length, see 5.5.3.1(2).
- I_s is the effective second moment of area of the stiffener, taken as that of its effective area A_s about the centroidal axis a - a of its effective cross-section, see figure 5.9.

(8) Alternatively, the elastic critical buckling stress $\sigma_{cr,s}$ may be obtained from elastic first order buckling analyses using numerical methods, see 5.5.1(8).

$$\sigma_{cr,s} = \frac{2\sqrt{0.153 \times 210000 \times 470.24}}{24.38} = 318.8 \ N/mm^2 \quad \ldots (5.15)$$

prEN 1993-1-3:2006; 5.5.3.1

(7) The reduction factor χ_d for the distortional buckling resistance (flexural buckling of a stiffener) should be obtained from the relative slenderness $\bar{\lambda}_d$ from:

$$\chi_d = 1{,}0 \quad \text{if } \bar{\lambda}_d \le 0{,}65 \quad \ldots (5.12a)$$

$$\chi_d = 1{,}47 - 0{,}723\bar{\lambda}_d \quad \text{if } 0{,}65 < \bar{\lambda}_d < 1{,}38 \quad \ldots (5.12b)$$

$$\chi_d = \frac{0{,}66}{\bar{\lambda}_d} \quad \text{if } \bar{\lambda}_d \ge 1{,}38 \quad \ldots (5.12c)$$

where:

$$\bar{\lambda}_d = \sqrt{f_{yb}/\sigma_{cr,s}} \quad \ldots (5.12d)$$

factor de reducción

$0.65 < \bar{\lambda}_d = \sqrt{\frac{235}{318.8}} = 0.858 < 1.38 \rightarrow \chi_d = 1.47 - 0.723 \times 0.859 = 0.849$ ... (5.12b)

(ver página 15 al final)

• 2ª vuelta con tensión $\sigma_{com,ED} = \chi_d \cdot f_y = 235 \times 0.849 = 199.51\ N/mm^2$

$\lambda_{pred} = \bar{\lambda}_p \sqrt{0.849} = 0.814 \times \sqrt{0.849} = 0.75$

cálculo de b_{e2}

(4.2) $\rho = \frac{0.75 - 0.055(3+1)}{0.75^2} = 0.942 \rightarrow b_{e2} = \frac{0.942 \times 37}{2} = 17.43$ mm.

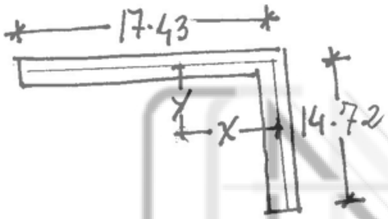
cálculo del labio

$\lambda_{pred} = 0.838 \times \sqrt{0.849} = 0.772 \rightarrow \rho = \frac{0.772 - 0.188}{0.772^2} = 0.98$ (4.3)

(>0.748)

$c_{eff} = 0.98 \times 15 = 14.72$ mm

• tensión crítica del rigidizador.



situación del centro de gravedad.

$Y = \frac{14.72 \times \frac{14.72}{2}}{14.72 + 17.43} = 3.36$; $X = \frac{17.43 \times \frac{17.43}{2}}{14.72 + 17.43} = 4.72$

$I_s = \frac{17.43 \times 0.8^3}{12} + \frac{0.8 \times 14.72^3}{12} + 17.43 \times 0.8 \times 3.36^2 + 14.72 \times 0.8 \left(\frac{14.72}{2} - 3.36\right)^2 = 559.2\ mm$

área del rigidizador: $A_s = (17.43 + 14.72) \times 0.8 = 25.72$

$k_1 = \frac{210000 \times 0.8^3}{4(1 - 0.3^2)} \cdot \frac{1}{(37 - 4.72)^2 100 + (37 - 4.72)^3 + 0.5(37 - 4.72)^2 100} = 0.15$

$\sigma_{cr} = \frac{2\sqrt{0.15 \times 210000 \times 559.2}}{25.72} = 331.75\ N/mm^2$

factor de reducción

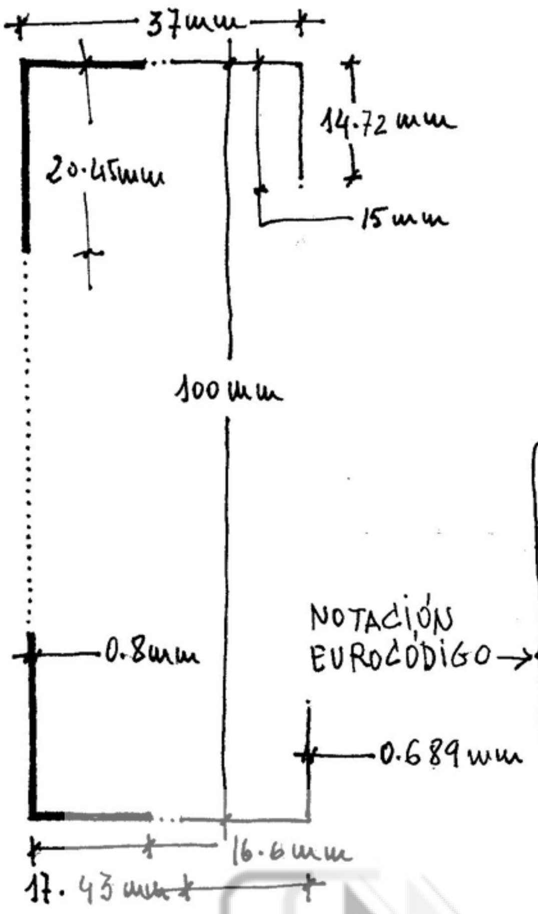
$0.65 < \lambda_d = \sqrt{\frac{235}{331.75}} = 0.841 < 1.38 \rightarrow \chi = 1.47 - 0.723 \times 0.841 = 0.862$ ... (5.12b)

Espesor del rigidizador: $t = 0.8 \times 0.862 = 0.689$ mm.

• sección eficaz del alma

(tabla 4.1) $\psi = 1 \rightarrow k = 4$ $\lambda_p = \frac{100/0.8}{28.4 \times \sqrt{4}} = 2.2 > 0.673$

$\rho = \frac{2.2 - 0.055(3+1)}{2.2^2} = 0.409 \rightarrow h_1 = h_2 = \frac{100 \times 0.409}{2} = 20.45$



Resistencia a compresión centrada de un perfil abierto en C de tres metros de longitud en el que se ha impedido la flexión respecto al eje de menor inercia cada 600 mm.

DATOS DE CUTWP4

Area = 163.2

$E = 210000\ N\,mm^{-2}$

$\nu = 0.3$

$G = \frac{E}{2(1+\nu)} = 80769.23\ N\,mm^{-2}$

NOTACIÓN EUROCÓDIGO →

$I_y = I_x = 258467$

$I_z = I_y = 35771.2$

$I_{yz} = I_{xy} = 0$

$I_t = J = 34.816$ X,Y(CDG) = 12.152; 50

$I_w = C_w = 8.42153E7$ X,Y(CORTADURA) = -18.92; 50

$i_y = \sqrt{258467/163.2} = 39.79 = R_x$ (AISIWIN)

$i_z = \sqrt{35771.2/163.2} = 14.8 = R_y$ (AISIWIN)

$y_0 = 12.152 + 18.9247 = 31.07 = X_0$ (AISIWIN)

...(6.33b) $i_0^2 = 39.79^2 + 14.8^2 + 31.07^2 = 2767.6 = R_0^2$ (AISIWIN)

$\beta = 1 - \frac{31.07^2}{2767.6} = 0.651$ ↳ (Beta) torsional flexural constant

$A_{eff} = 2\times[0.8\times(16.6+20.45)+0.689(14.72+17.43)] = 103.583$

6.2.2 Flexural buckling

(1) The design buckling resistance $N_{b,Rd}$ for flexural buckling should be obtained from EN 1993-1-1 using the appropriate buckling curve from table 6.3 according to the type of cross-section, axis of buckling and yield strength used, see (3).

(2) The buckling curve for a cross-section not included in table 6.3 may be obtained by analogy.

(3) The buckling resistance of a closed built-up cross-section should be determined using either:

- buckling curve b in association with the basic yield strength f_{yb} of the flat sheet material out of which the member is made by cold forming;
- buckling curve c in association with the average yield strength f_{ya} of the member after cold forming, determined as specified in 3.2.3, provided that $A_{eff} = A_g$.

6.2.3 Torsional buckling and torsional-flexural buckling

(1) For members with point-symmetric open cross-sections (e.g Z-purlin with equal flanges), account should be taken of the possibility that the resistance of the member to torsional buckling might be less than its resistance to flexural buckling.

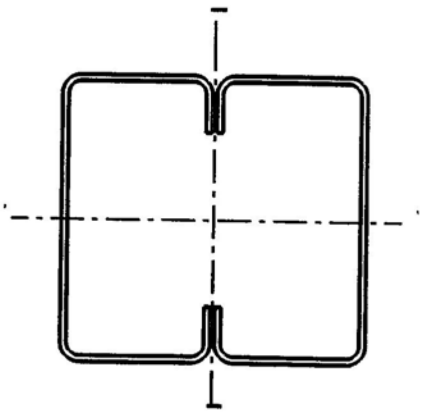
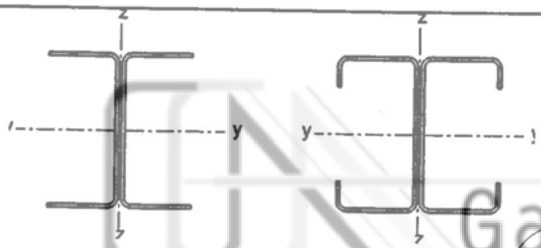
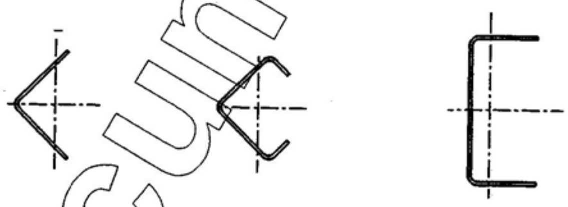
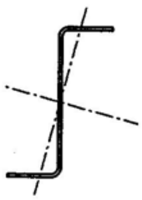
(2) For members with mono-symmetric open cross-sections, see figure 6.12, account should be taken of the possibility that the resistance of the member to torsional-flexural buckling might be less than its resistance to flexural buckling.

(3) For members with non-symmetric open cross-sections, account should be taken of the possibility that the resistance of the member to either torsional or torsional-flexural buckling might be less than its resistance to flexural buckling.

(4) The design buckling resistance $N_{b,Rd}$ for torsional or torsional-flexural buckling should be obtained from EN 1993-1-1, 6.3.1.1 using the relevant buckling curve for buckling about the z-z axis obtained from table 6.3.

8

Table 6.3: Appropriate buckling curve for various types of cross-section

Type of cross-section		Buckling about axis	Buckling curve
	if f_{yb} is used	Any	b
	if f_{ya} is used *)	Any	c
		y - y	a
		z - z	b
		Any	b
 or other cross-section		Any	c

*) The average yield strength f_{ya} should not be used unless $A_{eff} = A_g$

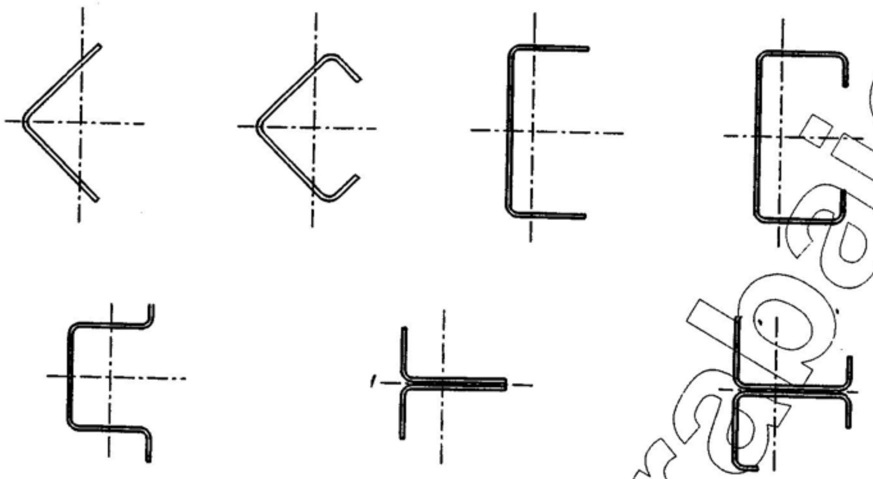


Figure 6.12: Cross-sections susceptible to torsional-flexural buckling

(5) The elastic critical force $N_{cr,T}$ for torsional buckling of simply supported beam should be determined from:

$$N_{cr,T} = \frac{1}{i_o^2}\left(G I_t + \frac{\pi^2 E I_w}{l_T^2}\right) \quad \text{... (6.33a)}$$

with:

$$i_o^2 = i_y^2 + i_z^2 + y_o^2 + z_o^2 \quad \text{... (6.33b)}$$

where:

- G is the shear modulus;
- I_t is the torsion constant of the gross cross-section;
- I_w is the warping constant of the gross cross-section;
- i_y is the radius of gyration of the gross cross-section about the y - y axis;
- i_z is the radius of gyration of the gross cross-section about the z - z axis;
- l_T is the buckling length of the member for torsional buckling;
- y_o, z_o are the shear centre co-ordinates with respect to the centroid of the gross cross-section.

(6) For doubly symmetric cross-sections (e.g. $y_o = z_o = 0$), the elastic critical force $N_{cr,TF}$ for torsional-flexural buckling should be determined from:

$$N_{cr,TF} = N_{cr,T} \quad \text{...(6.34)}$$

provided $N_{cr,T} < N_{cr,y}$ and $N_{cr,T} < N_{cr,z}$.

(7) For cross-sections that are symmetrical about the y - y axis (e.g. $z_o = 0$), the elastic critical force $N_{cr,TF}$ for torsional-flexural buckling should be determined from:

$$= \frac{N_{cr,y}}{2\beta}\left[1 + \frac{N_{cr,T}}{N_{cr,y}} - \sqrt{(1 - \frac{N_{cr,T}}{N_{cr,y}})^2 + 4(\frac{y_o}{i_o})^2 \frac{N_{cr,T}}{N_{cr,y}}}\right]$$

with:

$$\beta = 1 - \left(\frac{y_o}{i_o}\right)^2. \quad \text{... (6.35)}$$

6.3.1.1 Buckling resistance.

(3) The design buckling resistance of a compression member should be taken as:

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}} \quad \text{for Class 1, 2 and 3 cross-sections} \tag{6.47}$$

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \quad \text{for Class 4 cross-sections} \tag{6.48}$$

where χ is the reduction factor for the relevant buckling mode.

NOTE For determining the buckling resistance of members with tapered sections along the member or for non-uniform distribution of the compression force second order analysis according to 5.3.4(2) may be performed. For out-of-plane buckling see also 6.3.4.

(4) In determining A and A_{eff} holes for fasteners at the column ends need not to be taken into account.

6.3.1.2 Buckling curves

(1) For axial compression in members the value of χ for the appropriate non-dimensional slenderness $\bar{\lambda}$ should be determined from the relevant buckling curve according to:

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \quad \text{but } \chi \leq 1{,}0 \tag{6.49}$$

where $\Phi = 0{,}5\left[1 + \alpha\left(\bar{\lambda} - 0{,}2\right) + \bar{\lambda}^2\right]$

$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}}$ for Class 1, 2 and 3 cross-sections

$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}}$ for Class 4 cross-sections

α is an imperfection factor

N_{cr} is the elastic critical force for the relevant buckling mode based on the gross cross sectional properties.

(2) The imperfection factor α corresponding to the appropriate buckling curve should be obtained from Table 6.1 and Table 6.2.

Table 6.1: Imperfection factors for buckling curves

Buckling curve	a_0	a	b	c	d
Imperfection factor α	0,13	0,21	0,34	0,49	0,76

(3) Values of the reduction factor χ for the appropriate non-dimensional slenderness $\bar{\lambda}$ may be obtained from Figure 6.4.

(4) For slenderness $\bar{\lambda} \leq 0{,}2$ or for $\frac{N_{Ed}}{N_{cr}} \leq 0{,}04$ the buckling effects may be ignored and only cross sectional checks apply.

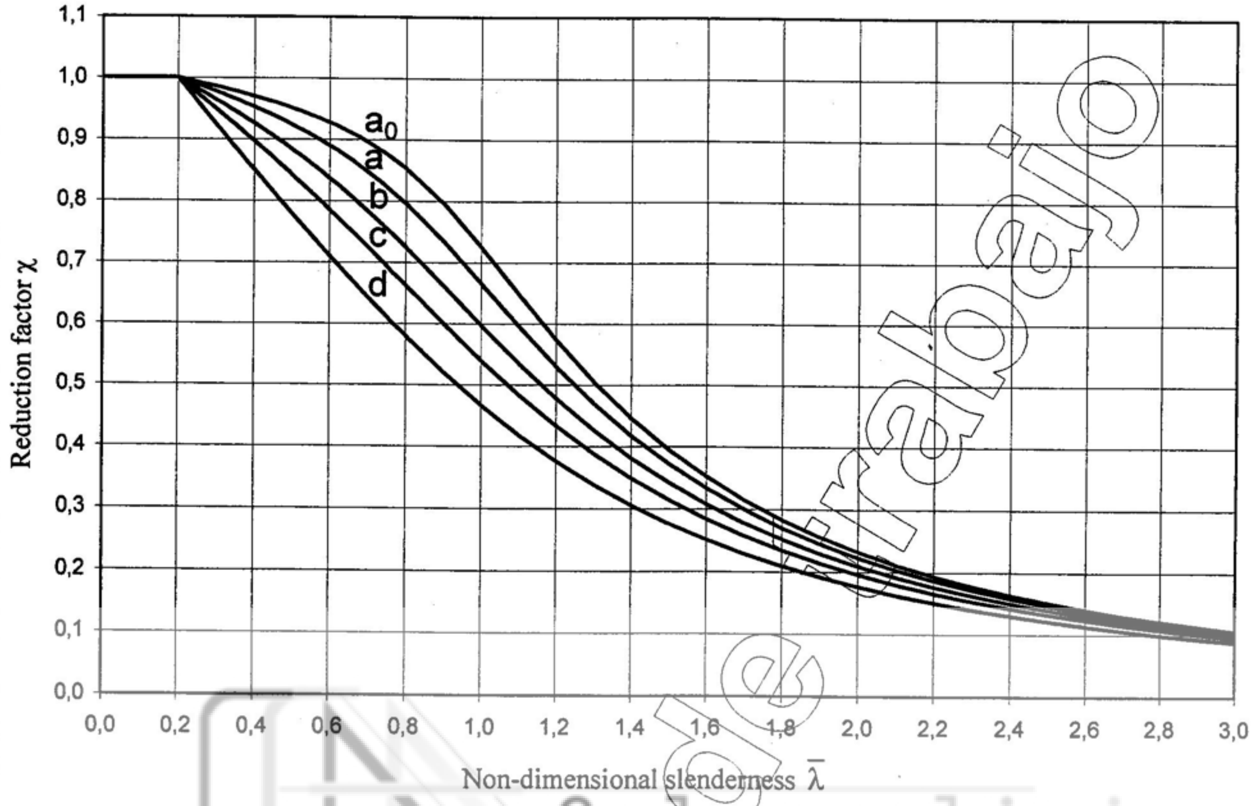


Figure 6.4: Buckling curves

$N_{cr,z} = \dfrac{\pi^2 210000 \times 35771.2}{600^2} = 205944 N$. $N_{cr,y} = \dfrac{\pi^2 210000 \times 258467}{3000^2} = 59522 N$

$N_{cr,T} = \dfrac{1}{2767.6}\left(80769.23 \times 34.8 + \dfrac{\pi^2 210000 \times 8425300}{600^2}\right) = 176204 N$

(EN 1993-1-3:2006; 6.2.3)

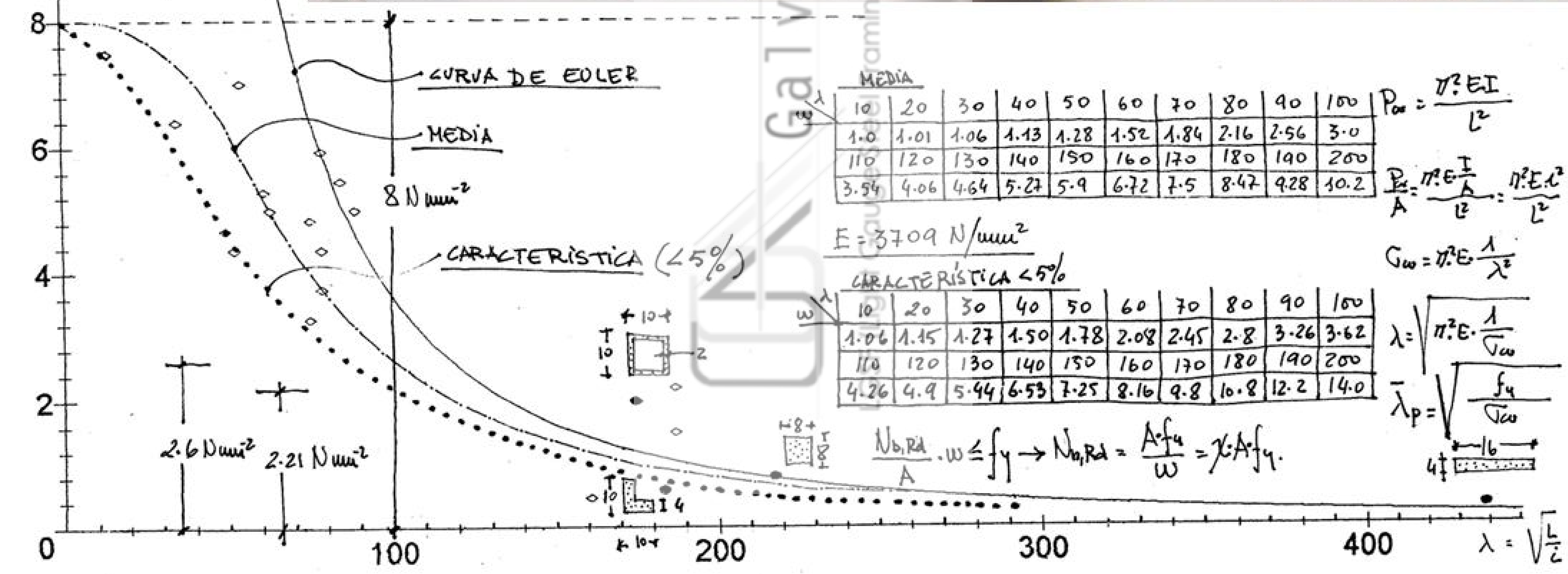
$\dfrac{N_{cr,T}}{N_{cr,y}} = \dfrac{176204}{59522.56} = 2.96$; $N_{cr,TF} = \dfrac{59522.56}{2 \times 0.651}\left[1+2.96-\sqrt{(1+2.96)^2 - 0.651 \times 2.96}\right] = 51943 N$

[EN 1993-1-3 ... (6.35)]

- El menor de todos es $N_{cr,TF} = 51943$ N.

$\bar{\lambda} = \sqrt{\dfrac{103.583 \times 235}{51943}} = 0.684$; $\Phi = 0.5\left(1+\underbrace{0.34}_{\alpha \text{ (buckling curve b)}}(0.684-0.2)+0.684^2\right) = 0.81$

(6.49) $\chi = \dfrac{1}{0.81+\sqrt{0.81^2-0.64^2}} = 0.765$ $\quad \underline{N_{RD}}$ (6.48) $= \dfrac{0.765 \times 103.583 \times 235}{\gamma_{M1}} = \dfrac{18621}{1} = \underline{18621} N$



MEDIA

λ	10	20	30	40	50	60	70	80	90	100
ω	1.0	1.01	1.06	1.13	1.28	1.52	1.84	2.16	2.56	3.0
λ	110	120	130	140	150	160	170	180	190	200
ω	3.54	4.06	4.64	5.27	5.9	6.72	7.5	8.47	9.28	10.2

$E = 3709\ N/mm^2$

CARACTERÍSTICA <5%

λ	10	20	30	40	50	60	70	80	90	100
ω	1.06	1.15	1.27	1.50	1.78	2.08	2.45	2.8	3.26	3.62
λ	110	120	130	140	150	160	170	180	190	200
ω	4.26	4.9	5.44	6.53	7.25	8.16	9.8	10.8	12.2	14.0

$$P_{cr} = \frac{\pi^2 E I}{L^2}$$

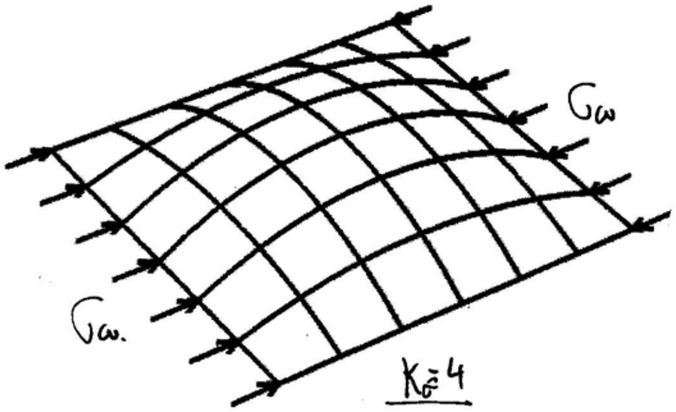
$$\frac{P_{cr}}{A} = \frac{\pi^2 E \frac{I}{A}}{L^2} = \frac{\pi^2 E i^2}{L^2}$$

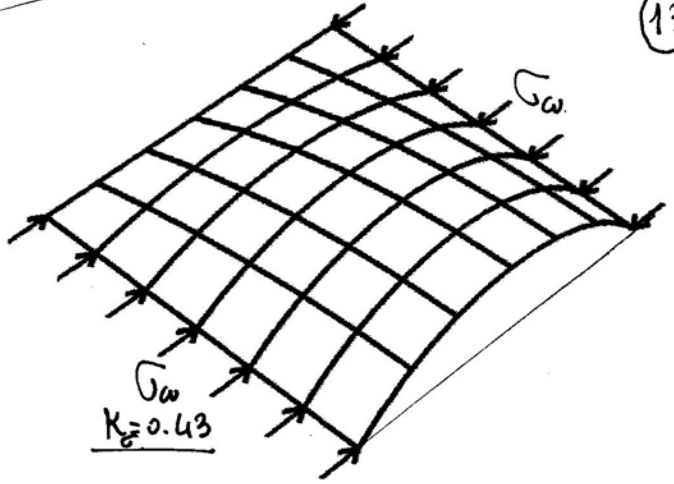
$$\sigma_{cr} = \pi^2 E \frac{1}{\lambda^2}$$

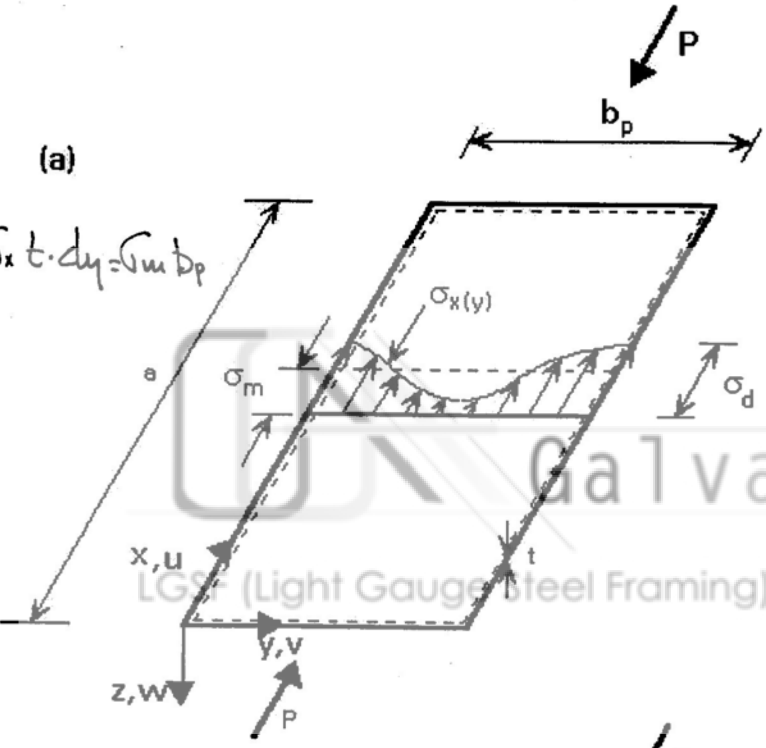
$$\lambda = \sqrt{\pi^2 E \cdot \frac{1}{\sigma_{cr}}}$$

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}}$$

$$\frac{N_{b,Rd}}{A} \cdot \omega \leq f_y \rightarrow N_{b,Rd} = \frac{A \cdot f_y}{\omega} = \chi \cdot A \cdot f_y$$





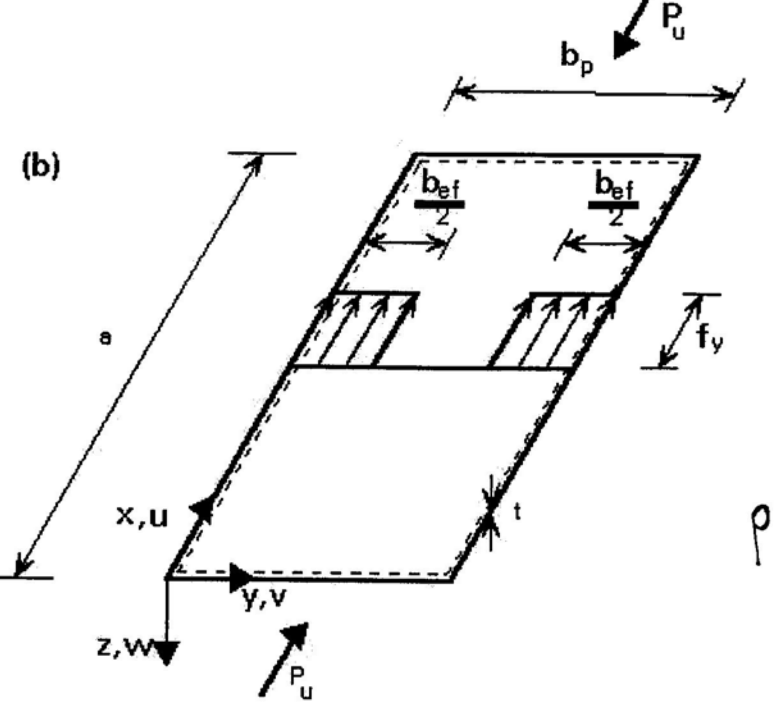


$$P = \int \sigma_x \, t \cdot dy = \sigma_m b_p$$

$$\sigma_{cr} = \frac{k_\sigma \pi^2 E}{12(1-\nu^2)(b_p/t)^2}$$

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{b_p}{t}\sqrt{\frac{f_y 12(1-\nu^2)}{k_\sigma \pi^2 E}} = \frac{b_p}{t\,\varepsilon}\sqrt{\frac{235 \times 12(1-\nu^2)}{k_\sigma \pi^2 E}} = \frac{b_p/t}{28.4\,\varepsilon\sqrt{k_\sigma}} \text{ (pag. 3)}$$

$E = 210000 \text{ N/mm}^2$



$$P_u = f_y \cdot b_{ef} \cdot t$$

$$b_{ef} = f(\sigma_{cr}, f_y)$$

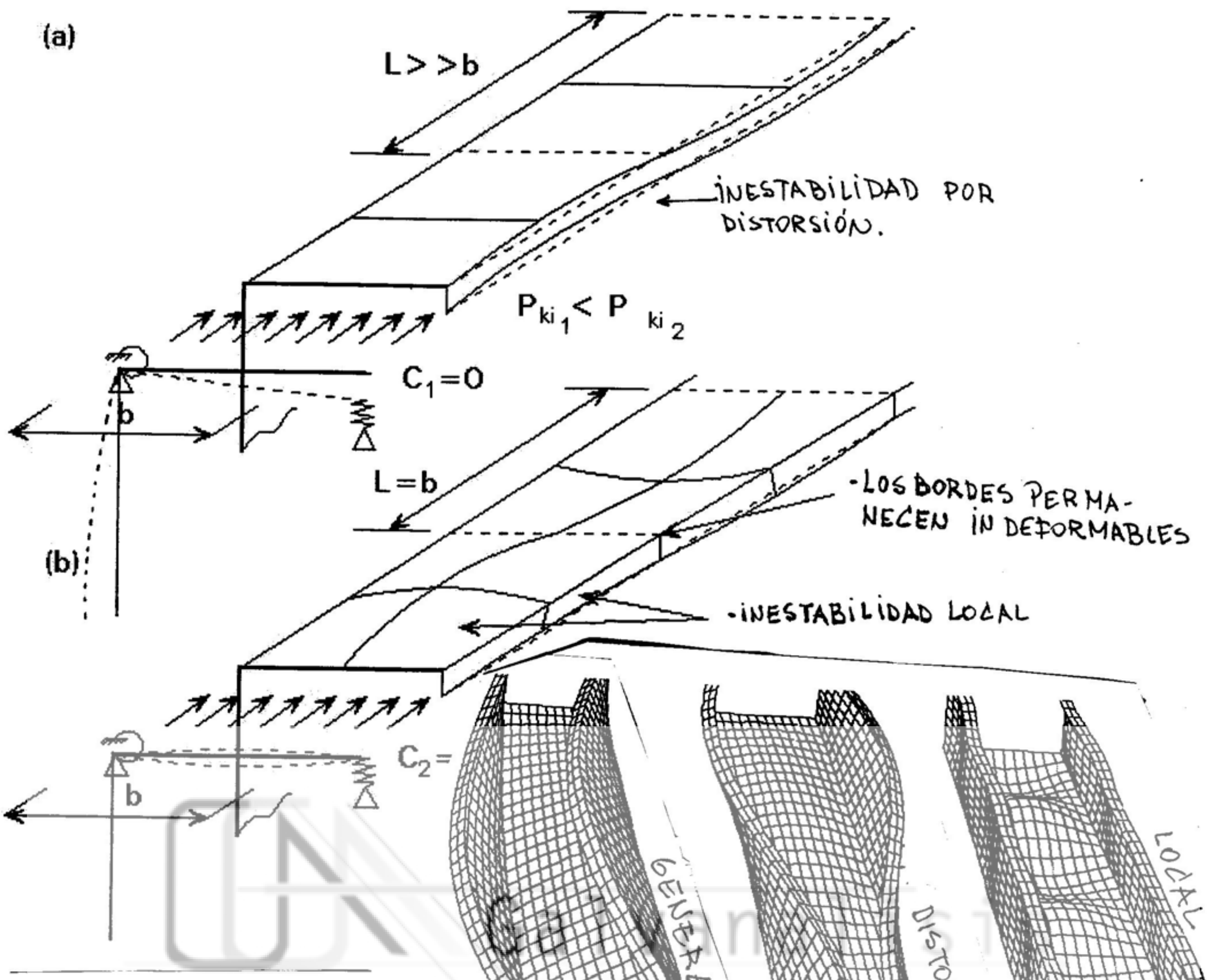
$$\frac{b_{ef}}{b_p} = \sqrt{\frac{\sigma_{cr}}{f_y}} \text{ (v.Karman)}$$

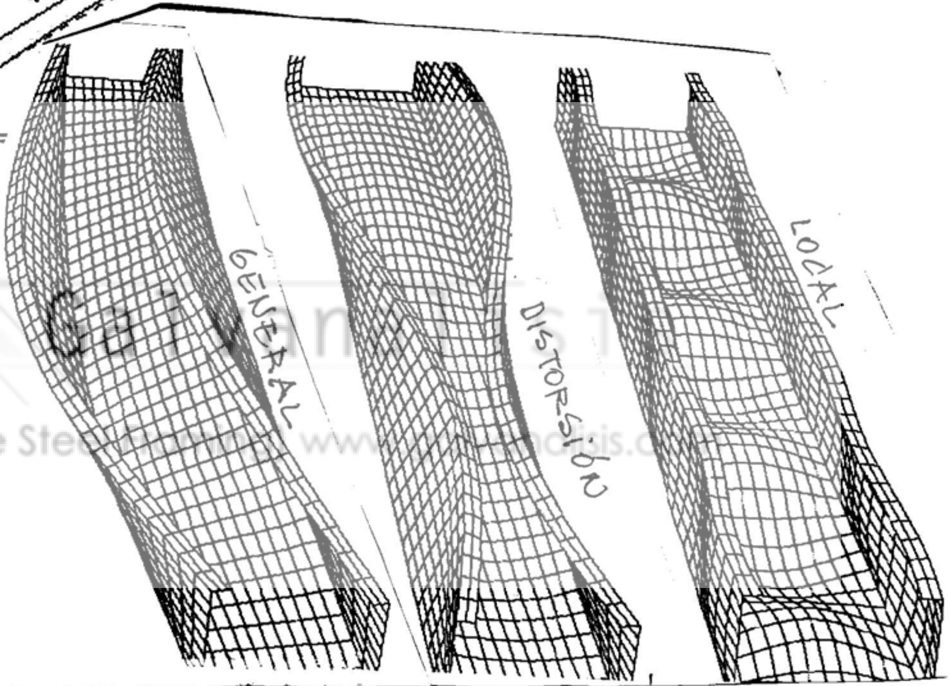
$$\rho = \frac{b_{ef}}{b_p} = \sqrt{\frac{\sigma_{cr}}{f_y}} \cdot \left(1 - 0{,}22\sqrt{\frac{\sigma_{cr}}{f_y}}\right)$$

(Winter)

$$= \frac{1}{\bar{\lambda}_p}\left(1 - 0.22\frac{1}{\bar{\lambda}_p}\right)$$

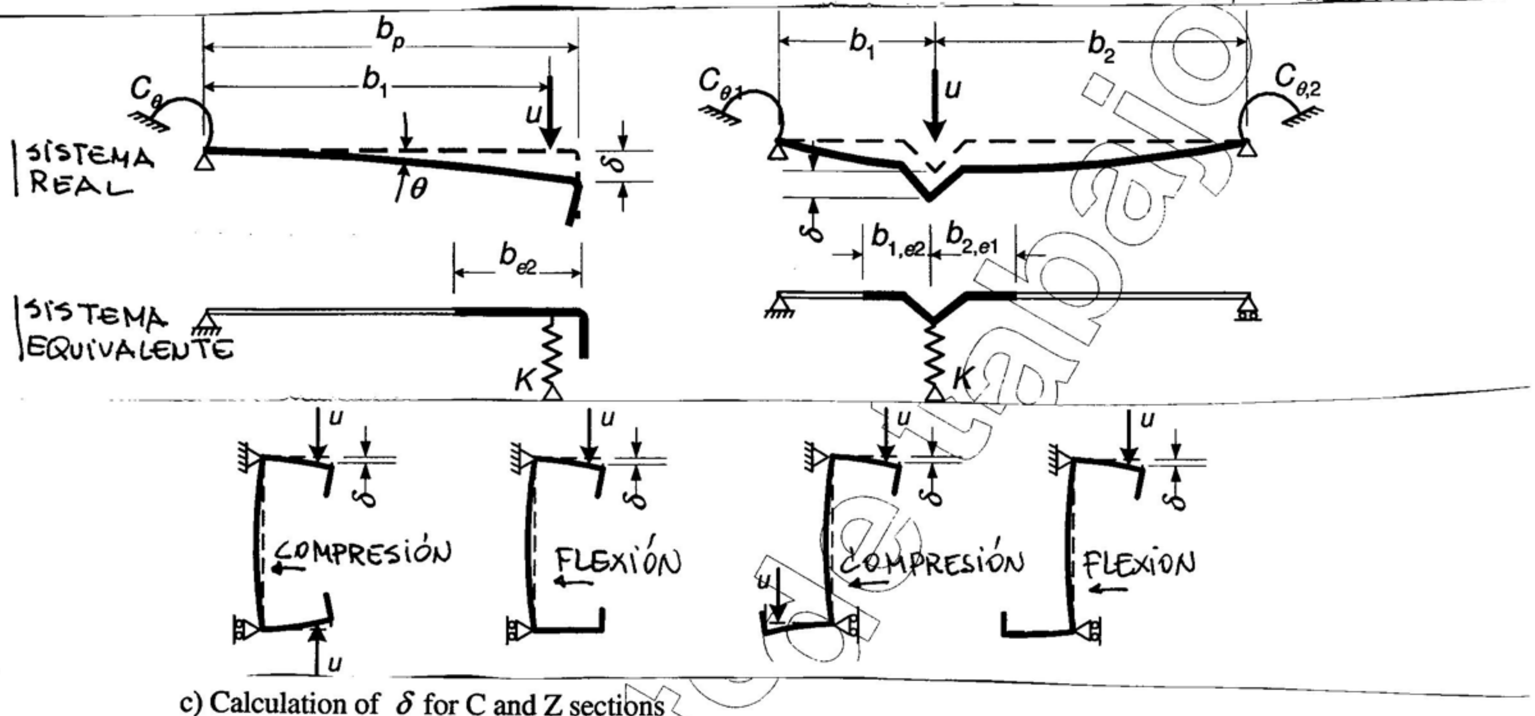
$$[\text{pag. } 3, (4.2)] \text{ para } \psi = 1 \rightarrow \rho = \frac{\bar{\lambda}_p - 0.055(3+\psi)}{\bar{\lambda}_p^2} = \frac{\bar{\lambda}_p - 0.22}{\bar{\lambda}_p^2} = \frac{1}{\bar{\lambda}_p}\left(1 - 0.22\frac{1}{\bar{\lambda}_p}\right)$$





$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s} \quad \ldots (5.15)$$ pag.5

EN 1993-1-3: 2006 (E)

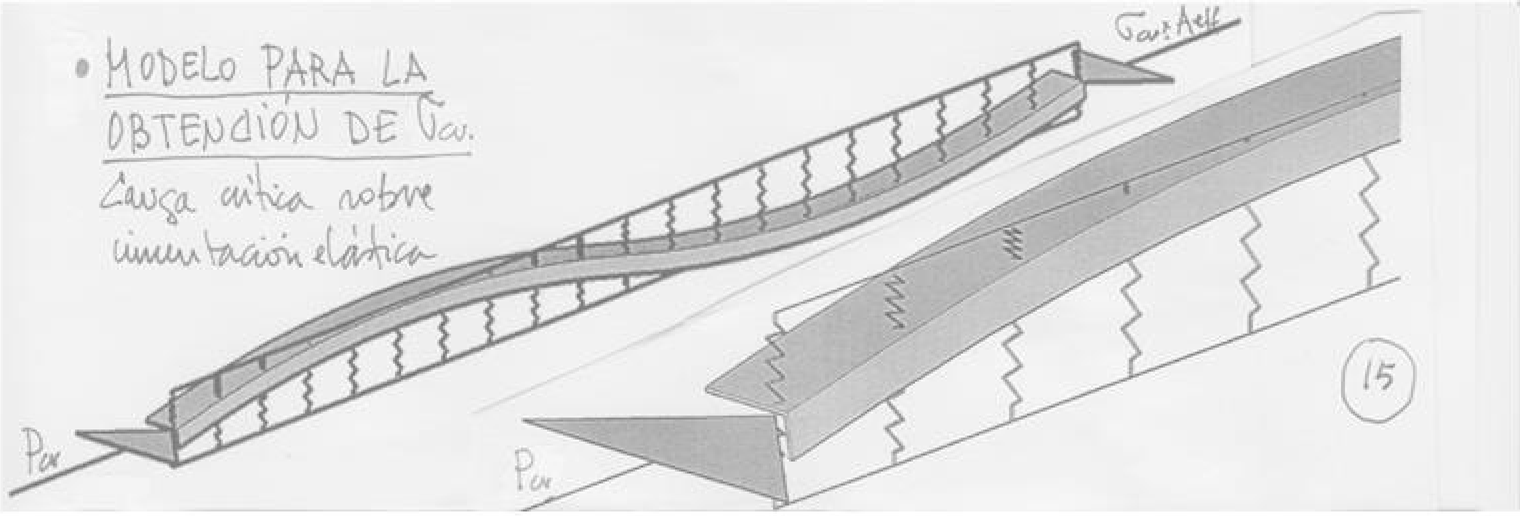


c) Calculation of δ for C and Z sections

Figure 5.6: Determination of spring stiffness

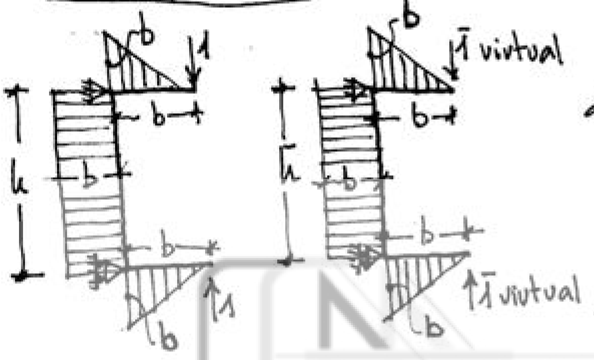
- MODELO PARA LA OBTENCIÓN DE σ_{cr}.

Carga crítica sobre cimentación elástica



OBTENCIÓN DE K $\longrightarrow \begin{cases} 1 = K\delta \\ K = \dfrac{1}{\delta} \end{cases}$ K = rigidez por unidad de longitud de chapa.

COMPRESIÓN



$$2\delta = \frac{1}{EI}\int M\bar{M}\,dx = \frac{1}{EI}\left[2\,\frac{b^2}{2}\times\frac{2}{3}b + b^2h\right]$$

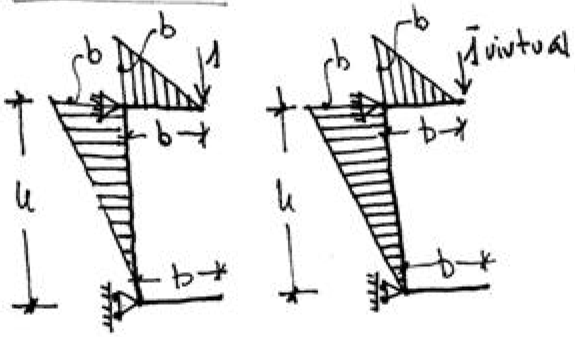
$$I = \frac{1\times t^3}{12}$$

$$2\delta = \frac{12}{Et^3}\left[\frac{2}{3}b^3 + b^2h\right] = \frac{4}{Et^3}\left[2b^3 + 3b^2h\right]$$

$$\delta = \frac{4}{Et^3}\left[b^3 + 1.5b^2h\right]$$

$$\frac{1}{\delta} = \frac{Et^3}{4}\,\frac{1}{\left[b^3 + 1.5b^2h\right]} = \underline{K}$$ (compárese con 5.10b, p.5)

FLEXIÓN



$$\delta = \frac{1}{EI}\left[\frac{b^2}{2}\,\frac{2}{3}b + \frac{bh}{2}\times\frac{2}{3}b\right]$$

$$I = \frac{1\times t^3}{12}$$

$$\delta = \frac{12}{Et^3}\left[\frac{1}{3}b^3 + \frac{1}{3}b^2h\right] = \frac{4}{Et^3}\left[b^3 + b^2h\right]$$

$$\frac{1}{\delta} = \frac{Et^3}{4}\,\frac{1}{(b^3 + b^2h)} = \underline{K}$$ (compárese con 5.10b, p.5)

- en ambos casos no se ha tenido en cuenta ν para hacer más sencillo el desarrollo.

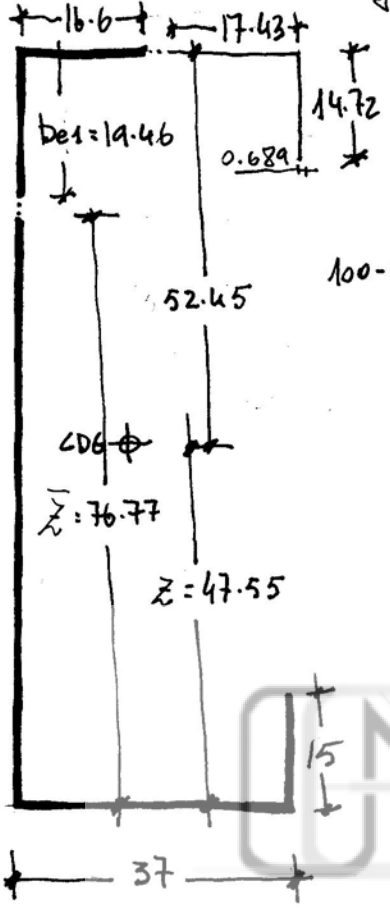
¿Por qué en la página 6 (y en general en cada vuelta) $\lambda_{p,red} = \lambda_p\sqrt{\chi_d} = 0.814\sqrt{0.849}$?

- 2ª vuelta con tensión $\sigma_{com,Ed} = \chi_d \cdot f_y$; $\varepsilon = \sqrt{\dfrac{235}{f_y}}$

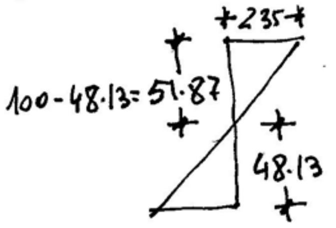
$$\bar{\lambda}_p = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}\,;\quad \lambda_{p,red} = \frac{\bar{b}/t}{28.4\,\dfrac{\varepsilon}{\sqrt{\chi_d}}\sqrt{k_\sigma}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}\cdot\sqrt{\chi_d} = \underline{\underline{\bar{\lambda}_p\sqrt{\chi_d}}}$$

SECCIÓN EFICAZ A FLEXIÓN (ver EN 1993-1-3:2006; 5.5.2.(3))

- Ala y labio superiores igual que a compresión centrada según EN 1993-1-3 (3)



$$z=\frac{\overbrace{(14.72\times 92.64+17.43\times 100)\times 0.689+(16.6\times 100)\times 0.8+(100\times 50+15\times 7.5)\times 0.8}^{3468.5}}{\underbrace{(17.43+14.72)\times 0.689+16.6\times 0.8}_{35.43}+(100+37+15)\,0.8}=48.13$$



$0>\psi>-1$

$$\psi=\frac{-48.13}{51.87}=-0.927;\ k=7.81-6.29(-0.927)+9.78(-0.927)^2=22.04$$

$$\bar{\lambda}_p=\frac{100/0.8}{28.4\sqrt{22.04}}=0.937\rightarrow \rho=\frac{0.937-0.055(3-0.927)}{(0.937)^2}=0.937$$

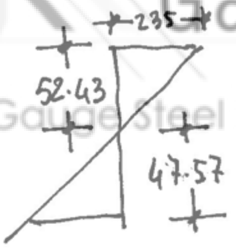
$b_{eff}=51.87\times 0.937=48.6$

$b_{e1}=19.44=b_{eff}\times 0.4$

$b_{e2}=29.16=b_{eff}\times 0.6$

$\bar{z}=48.13+29.16=77.29$

$$z=\frac{3468.5+\left(19.44\times 90.28+\frac{77.29^2}{2}+15\times 7.5\right)0.8}{35.43+(19.6+77.29+37+15)\,0.8}=47.57$$



$$\psi=\frac{-47.57}{52.43}=-0.91;\ K=7.81-6.29(-0.91)+9.78(-0.91)^2=21.63$$

$$\bar{\lambda}_p=\frac{100/0.8}{28.4\sqrt{21.63}}=0.946\rightarrow \rho=\frac{0.946-0.055(3-0.91)}{0.946^2}=0.928$$

$b_{eff}=52.43\times 0.928=48.65$

$b_{e1}=19.46=b_{eff}\times 0.4$

$b_{e2}=29.2=b_{eff}\times 0.6$

$\bar{z}=47.57+29.2=76.77$

$$z=\frac{3468.5+\left(19.46\times 90.27+\frac{76.77^2}{2}+15\times 7.5\right)0.8}{35.43+(19.46+76.77+37+15)\,0.8}=47.55$$

PROPIEDADES DE LA SECCIÓN EFICAZ

$$I_{y_{eff}}=\frac{1}{12}\left(0.689\times 14.72^3+17.43\times 0.689^3+16.6\times 0.8^3+0.8\times 19.4^3+0.8\times 76.77^3+37\times 0.8^3+0.8\times 15^3\right)+$$
$$+14.72\times 0.689\times 45.09^2+17.43\times 0.689\times 52.45+16.6\times 0.8\times 52.45^2+19.46\times 0.8\times 42.72^2+$$
$$+76.77\times 0.8\times (9.16)^2+37\times 0.8\times 47.55^2+15\times 0.8\times 40.05^2=240995\ mm^4$$

$$W_{y_{eff}}=\frac{240942.6}{52.45}=4594\ mm^3$$

6.2.4 Lateral-torsional buckling of members subject to bending

(1) The design buckling resistance moment of a member that is susceptible to lateral-torsional buckling should be determined according to EN 1993-1-1, section 6.3.2.2 using the lateral buckling curve a or b.

(2) This method should not be used for the sections that have a significant angle between the principal axes of the effective cross-section, compared to those of the gross cross-section.

6.3.2.2 Lateral torsional buckling curves – General case

(1) Unless otherwise specified, see 6.3.2.3, for bending members of constant cross-section, the value of χ_{LT} for the appropriate non-dimensional slenderness $\bar{\lambda}_{LT}$, should be determined from:

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}} \quad \text{but } \chi_{LT} \le 1{,}0$$

$$* \; M_{cr} = \frac{\pi^2 E I_z}{L^2} \times \sqrt{\frac{I_w}{I_z} + \frac{L^2 G I_t}{\pi^2 E I_z}}$$

(simply supported end conditions)

where $\Phi_{LT} = 0{,}5\left[1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0{,}2\right) + \bar{\lambda}_{LT}^2\right]$

α_{LT} is an imperfection factor

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_y f_y}{M_{cr}}}$$

M_{cr} is the elastic critical moment for lateral-torsional buckling * AISI STANDARD C3.1.2.1

(2) M_{cr} is based on gross cross sectional properties and takes into account the loading conditions, the real moment distribution and the lateral restraints.

NOTE The imperfection factor α_{LT} corresponding to the appropriate buckling curve may be obtained from the National Annex. The recommended values α_{LT} are given in Table 6.3.

Table 6.3: Recommended values for imperfection factors for lateral torsional buckling curves

Buckling curve	a	b	c	d
Imperfection factor α_{LT}	0,21	0,34	0,49	0,76

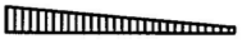
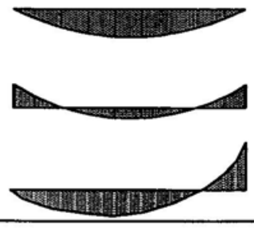
$$M_{cr} = \frac{\pi^2 \times 210000 \times 35771.2}{600^2} \times \sqrt{\frac{84215300}{35771.2} + \frac{600^2 \times 80769.23 \times 34.816}{\pi^2 \times 210000 \times 35771.2}} = 10021542.64 \text{ N.mm}$$

$$\bar{\lambda}_{LT} = \sqrt{\frac{4594 \times 235}{10021542.64}} = 0.328 \qquad \Phi_{LT} = 0.5\left[1 + \underbrace{0.34}_{\alpha_{LT}}(0.328 - 0.2) + 0.328^2\right] = 0.575$$

$$\chi_{LT} = \frac{1}{0.575 + \sqrt{0.575^2 - 0.328^2}} = 0.954$$

$$\underline{\underline{M}} = 0.954 \times \frac{4592 \times 235}{1} = \underline{\underline{1029928 \text{ Nmm}}}$$

Table 6.6: Correction factors k_c

Moment distribution	k_c
 $\psi = 1$	1,0
 $-1 \le \psi \le 1$	$\dfrac{1}{1{,}33 - 0{,}33\psi}$
	0,94 0,90 0,91
	0,86 0,77 0,82

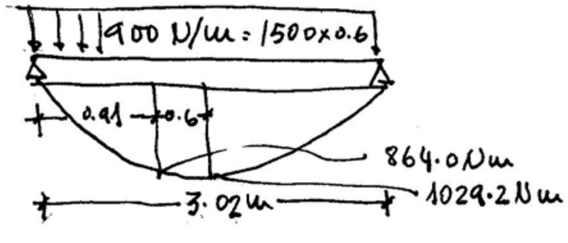
(2) For taking into account the moment distribution between the lateral restraints of members the reduction factor χ_{LT} may be modified as follows:

$$\chi_{LT,mod} = \frac{\chi_{LT}}{f} \quad \text{but } \chi_{LT,mod} \le 1 \qquad (6.58)$$

NOTE The values f may be defined in the National Annex. The following minimum values are recommended:

$$f = 1 - 0{,}5(1-k_c)[1 - 2{,}0(\bar{\lambda}_{LT} - 0{,}8)^2] \qquad \text{but } f \le 1{,}0$$

k_c is a correction factor according to Table 6.6



$\psi = \frac{864}{1029.2} = 0.839$; $k_c = \frac{1}{1.33 - 0.33 \times 0.839} = 0.95$

$f = 1 - 0.5(1-0.95)[1 - 2.0(0.328-0.8)^2] = 0.986$

$\chi_{LTmod} = \frac{0.954}{0.986} = 0.967$

$M = 0.967 \times 4594 \times 235 = 1043963$ Nmm.

FLECHAS

(3) The second moment of area may be calculated alternatively by interpolation of gross cross-section and effective cross-section using the expression

EN 1993-1-3: 2006 (E)

$$I_{fic} = I_{gr} - \frac{\sigma_{gr}}{\sigma}(I_{gr} - I(\sigma)_{eff}) \qquad \ldots (7.1)$$

where

- I_{gr} is second moment of area of the gross cross-section;
- σ_{gr} is maximum compressive bending stress in the serviceability limit state, based on the gross cross-section (positive in formula);
- $I(\sigma)_{eff}$ is the second moment of area of the effective cross-section with allowance for local buckling calculated for a maximum stress $\sigma \ge \sigma_{gr}$, in which the maximum stress is the largest absolute value of stresses within the calculation length considered.

6.1.5 Shear force

(1) The shear resistance $V_{b,Rd}$ should be determined from:

$$V_{b,Rd} = \frac{\dfrac{h_w}{\sin\phi} t f_{bv}}{\gamma_{M0}} \quad \text{... (6.8)}$$

where:

f_{bv} is the shear strength considering buckling according to Table 6.1;

h_w is the web height between the midlines of the flanges, see figure 5.3(c);

ϕ is the slope of the web relative to the flanges, see figure 6.5.

$\gamma_{M0} = 1$ (recomendado)

Table 6.1: Shear buckling strength f_{bv}

Relative web slenderness	Web without stiffening at the support	Web with stiffening at the support [1)]
$\overline{\lambda}_w \leq 0{,}83$	$0{,}58\ f_{yb}$	$0{,}58\ f_{yb}$
$0{,}83 < \overline{\lambda}_w < 1{,}40$	$0{,}48 f_{yb} / \overline{\lambda}_w$	$0{,}48 f_{yb} / \overline{\lambda}_w$
$\overline{\lambda}_w \geq 1{,}40$	$0{,}67 f_{yb} / \overline{\lambda}_w^2$	$0{,}48 f_{yb} / \overline{\lambda}_w$

[1)] Stiffening at the support, such as cleats, arranged to prevent distortion of the web and designed to resist the support reaction.

(2) The relative web slenderness $\overline{\lambda}_w$ should be obtained from the following:

- for webs without longitudinal stiffeners:

$$\overline{\lambda}_w = 0{,}346 \frac{s_w}{t} \sqrt{\frac{f_{yb}}{E}} \quad \text{... (6.10a)}$$

- for webs with longitudinal stiffeners, see figure 6.5:

$$\overline{\lambda}_w = 0{,}346 \frac{s_d}{t} \sqrt{\frac{5{,}34}{k_\tau} \frac{f_{yb}}{E}} \quad \text{but} \quad \overline{\lambda}_w \geq 0{,}346 \frac{s_p}{t} \sqrt{\frac{f_{yb}}{E}} \quad \text{... (6.10b)}$$

with:

$$k_\tau = 5{,}34 + \frac{2{,}10}{t} \left(\frac{\Sigma I_s}{s_d} \right)^{1/3}$$

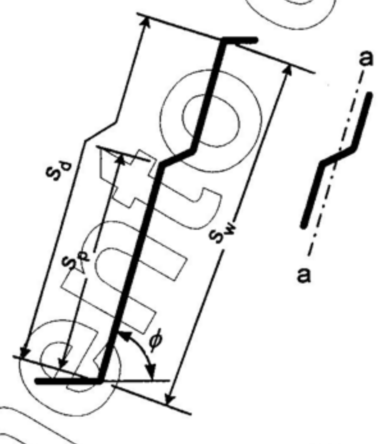
where:

I_s is the second moment of area of the individual longitudinal stiffener as defined in 5.5.3.4.3(7), about the axis a – a as indicated in figure 6.5;

s_d is the total developed slant height of the web, as indicated in figure 6.5;

s_p is the slant height of the largest plane element in the web, see figure 6.5;

s_w is the slant height of the web, as shown in figure 6.5, between the midpoints of the corners, these points are the median points of the corners, see figure 5.3(c).



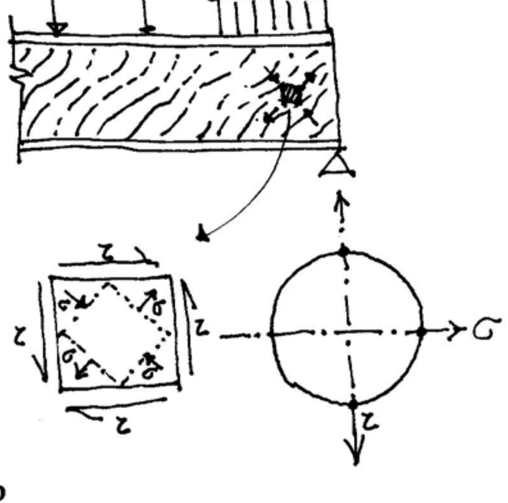


Figure 6.5: Longitudinally stiffened web

6.1.8 Combined tension and bending

(1) Cross-sections subject to combined axial tension N_{Ed} and bending moments $M_{y,Ed}$ and $M_{z,Ed}$ should satisfy the criterion:

$$\frac{N_{Ed}}{N_{t,Rd}} + \frac{M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed}}{M_{cz,Rd,ten}} \leq 1 \qquad \text{... (6.23)}$$

where:

$N_{t,Rd}$ is the design resistance of a cross-section for uniform tension (6.1.2);

$M_{cy,Rd,ten}$ is the design moment resistance of a cross-section for maximum tensile stress if subject only to moment about the y - y axis (6.1.4);

$M_{cz,Rd,ten}$ is the design moment resistance of a cross-section for maximum tensile stress if subject only to moment about the z - z axis (6.1.4).

(2) If $M_{cy,Rd,com} \leq M_{cy,Rd,ten}$ or $M_{cz,Rd,com} \leq M_{cz,Rd,ten}$ (where $M_{cy,Rd,com}$ and $M_{cz,Rd,com}$ are the moment resistances for the maximum compressive stress in a cross-section that is subject only to moment about the relevant axis), the following criterion should also be satisfied:

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1 \qquad \text{... (6.24)}$$

6.1.9 Combined compression and bending

(1) Cross-sections subject to combined axial compression N_{Ed} and bending moments $M_{y,Ed}$ and $M_{z,Ed}$ should satisfy the criterion:

$$\frac{N_{Ed}}{N_{c,Rd}} + \frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,com}} \leq 1 \qquad \text{... (6.25)}$$

in which $N_{c,Rd}$ is as defined in 6.1.3, $M_{cy,Rd,com}$ and $M_{cz,Rd,com}$ are as defined in 6.1.8.

(2) The additional moments $\Delta M_{y,Ed}$ and $\Delta M_{z,Ed}$ due to shifts of the centroidal axes should be taken as:

$$\Delta M_{y,Ed} = N_{Ed}\, e_{Ny}$$

$$\Delta M_{z,Ed} = N_{Ed}\, e_{Nz}$$

in which e_{Ny} and e_{Nz} are the shifts of y-y and z-z centroidal axis due to axial forces, see 6.1.3(3).

(3) If $M_{cy,Rd,ten} \leq M_{cy,Rd,com}$ or $M_{cz,Rd,ten} \leq M_{cz,Rd,com}$ the following criterion should also be satisfied:

$$\frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,ten}} - \frac{N_{Ed}}{N_{c,Rd}} \leq 1 \qquad \text{... (6.26)}$$

in which $M_{cy,Rd,ten}$, $M_{cz,Rd,ten}$ are as defined in 6.1.8.

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6.1.10 Combined shear force, axial force and bending moment

(1) For cross-sections subject to the combined action of an axial force N_{Ed}, a bending moment M_{Ed} and a shear force V_{Ed} no reduction due to shear force need not be done provided that $V_{Ed} \leq 0{,}5\, V_{w,Rd}$. If the shear force is larger than half of the shear force resistance then following equations should be satisfied:

$$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \left(1 - \frac{M_{f,Rd}}{M_{pl,Rd}}\right)\left(\frac{2V_{Ed}}{V_{w,Rd}} - 1\right)^2 \leq 1{,}0 \qquad \text{...(6.27)}$$

where:

N_{Rd} is the design resistance of a cross-section for uniform tension or compression given in 6.1.2 or 6.1.3;

$M_{y,Rd}$ is the design moment resistance of the cross-section given in 6.1.4;

$V_{w,Rd}$ is the design shear resistance of the web given in 6.1.5(1);

$M_{f,Rd}$ is the design plastic moment resistance of a cross-section consisting only of flanges, see EN 1993-1-5;

$M_{pl,Rd}$ is the plastic moment resistance of the cross-section, see EN 1993-1-5.

For members and sheeting with more than one web $V_{w,Rd}$ is the sum of the resistances of the webs. See also EN 1993-1-5.

6.1.11 Combined bending moment and local load or support reaction

(1) Cross-sections subject to the combined action of a bending moment M_{Ed} and a transverse force due to a local load or support reaction F_{Ed} should satisfy the following:

$$M_{Ed} / M_{c,Rd} \leq 1 \qquad \text{... (6.28a)}$$

$$F_{Ed} / R_{w,Rd} \leq 1 \qquad \text{... (6.28b)}$$

$$\frac{M_{Ed}}{M_{c,Rd}} + \frac{F_{Ed}}{R_{w,Rd}} \leq 1{,}25 \qquad \text{... (6.28c)}$$

where:

$M_{c,Rd}$ is the moment resistance of the cross-section given in 6.1.4.1(1);

$R_{w,Rd}$ is the appropriate value of the local transverse resistance of the web from 6.1.7.

In equation (6.2.8c) the bending moment M_{Ed} may be calculated at the edge of the support. For members and sheeting with more than one web, $R_{w,Rd}$ is the sum of the local transverse resistances of the individual webs.

Table 8.2: Design resistances for self-tapping screws [1)]

Screws loaded in shear:

Bearing resistance: $F_{b,Rd} = \alpha f_u d t / \gamma_{M2}$

In which α is given by the following:

- if $t = t_1$: $\alpha = 3{,}2\sqrt{t/d}$ but $\alpha \leq 2{,}1$
- if $t_1 \langle 2{,}5t$ and $t < 1{,}0$ mm: $\alpha = 3{,}2\sqrt{t/d}$ but $\alpha \leq 2{,}1$
- if $t_1 \langle 2{,}5t$ and $t \langle 1{,}0$ mm: $\alpha = 2{,}1$
- if $t < t_1 < 2{,}5t$: obtain α by linear interpolation.

Net-section resistance: $F_{n,Rd} = A_{net} f_u / \gamma_{M2}$

Shear resistance: Shear resistance $F_{v,Rd}$ to be determined by testing *[2)]

$F_{v,Rd} = F_{v,Rk} / \gamma_{M2}$

d: diámetro "nominal" del tornillo.
t: espesor chapa delgada.
t_1: " " gruesa.
γ_{M2} = 1.25 (recomendado)
A_{net} = sección neta resistida.

Conditions: [4)] $F_{v,Rd} \geq 1{,}2 F_{b,Rd}$ or $\Sigma F_{v,Rd} \geq 1{,}2 F_{n,Rd}$

Screws loaded in tension:

Pull-through resistance: [2)]

- for static loads: $F_{p,Rd} = d_w t f_u / \gamma_{M2}$
- for screws subject to wind loads and combination of wind loads and static loads: $F_{p,Rd} = 0{,}5\, d_w t f_u / \gamma_{M2}$

Pull-out resistance: If $t_{sup} / s < 1$: $F_{o,Rd} = 0{,}45\, d\, t_{sup} f_{u,sup} / \gamma_{M2}$ (s is the thread pitch)

If $t_{sup} / s \langle 1$: $F_{o,Rd} = 0{,}65\, d\, t_{sup} f_{u,sup} / \gamma_{M2}$

Tension resistance: Tension resistance $F_{t,Rd}$ to be determined by testing *[2)].

Conditions: [4)] $F_{t,Rd} \geq \Sigma F_{p,Rd}$ or $F_{t,Rd} \geq F_{o,Rd}$

Range of validity: [3)]

Generally: $e_1 \geq 3d$ $p_1 \geq 3d$ $3{,}0 \text{ mm} \leq d \leq 8{,}0 \text{ mm}$

$e_2 \geq 1{,}5d$ $p_2 \geq 3d$

e_1 y e_2 ver figura pag. 24

For tension: $0{,}5 \text{ mm} \leq t \leq 1{,}5 \text{ mm}$ and $t_1 \geq 0{,}9$ mm

$f_u \leq 550$ Mpa

[1)] In this table it is assumed that the thinnest sheet is next to the head of the screw.
[2)] These values assume that the washer has sufficient rigidity to prevent it from being deformed appreciably or pulled over the head of the fastener.
[3)] Self-tapping screws may be used beyond this range of validity if the resistance is determined from the results of tests.
[4)] The required conditions should be fulfilled when deformation capacity of the connection is needed. When these conditions are not fulfilled there should be proved that the needed deformation capacity will be provided by other parts of the structure.

NOTE*[2)] The National Annex may give further information on shear resistance of self-tapping skrews loaded in shear and tension resistance of self-tapping skrews loaded in tension.

Annex B [informative] – Durability of fasteners

(1) In Construction Classes I, II and III table B.1 may be applied.

Table B.1: Fastener material with regard to corrosion environment (and sheeting material only for information). Only the risk of corrosion is considered. Classification of environment according to EN ISO 12944-2.

Classification of environment	Sheet material	Material of fastener					
		Aluminium	Electro galvanized steel. Coat thickness > 7μm	Hot-dip zinc coated steel[b]. Coat thickness >45μm	Stainless steel, case hardened. 1.4006[d]	Stainless steel, 1.4301[d] 1.4436[d]	Monel[a]
C1	A, B, C	X	X	X	X	X	X
	D, E, S	X	X	X	X	X	X
C2	A	X	-	X	X	X	X
	C, D, E	X	-	X	X	X	X
	S	X	-	X	X	X	X
C3	A	X	-	X	-	X	X
	C, E	X	-	X	(X)[c]	(X)[c]	-
	D	X	-	X	-	(X)[c]	X
	S	-	-	X	X	X	X
C4	A	X	-	(X)[c]	-	(X)[c]	-
	D	-	-	X	-	(X)[c]	-
	E	X	-	X	-	(X)[c]	-
	S	-	-	X	-	X	X
C5-I	A	X	-	-	-	(X)[c]	-
	D[f]	-	-	X	-	(X)[c]	-
	S	-	-	-	-	X	-
C5-M	A	X	-	-	-	(X)[c]	-
	D[f]	-	-	X	-	(X)[c]	-
	S	-	-	-	-	X	-

Anm. Fastener of steel without coating may be used in corrosion classification class C1.

A = Aluminium irrespective of surface finish

B = Un-coated steel sheet

* C = Hot-dip zinc coated (Z275) or aluzink coated (AZ150) steel sheet

D = Hot-dip zinc coated steel sheet + coating of paint or plastics

E = Aluzink coated (AZ185) steel sheet

S = Stainless steel

X = Type of material recommended from the corrosion standpoint

(X) = Type of material recommended from the corrosion standpoint under the specified condition only

\- = Type of material not recommended from the corrosion standpoint

a Refers to rivets only

b Refers to screws and nuts only

c Insulating washer, of material resistant to ageing, between sheeting and fastener

d Stainless steel EN 10 088

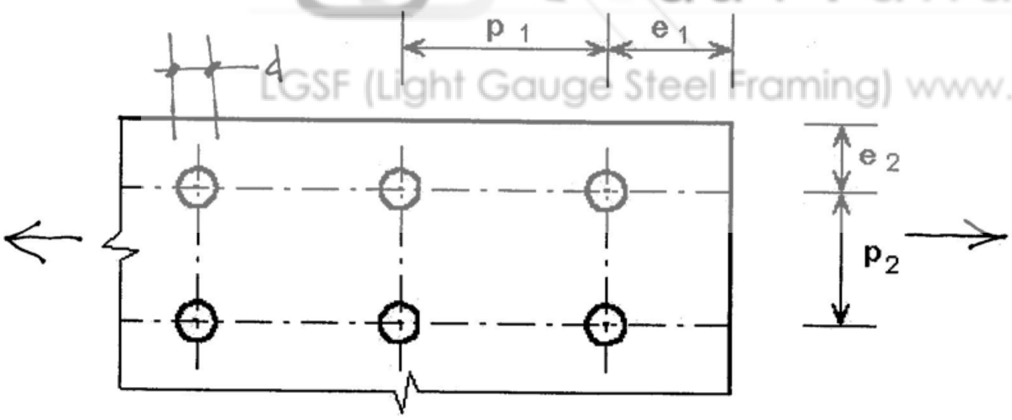
e Risk of discoloration.

f Always check with sheet supplier

(2) The environmental classification following EN-ISO 12944-2 is presented in table B.2.

Table B.2: Atmospheric-corrosivity categories according to EN ISO 12944-2 and examples of typical environments

Corro-sivity category	Corro-sivity level	Examples of typical environments in a temperate climate (informative))	
		Exterior	Interior
C1	Very low	-	Heated buildings with clean atmospheres, e. g. offices, shops, schools and hotels.
C2	Low	Atmospheres with low level of pollution. Mostly rural areas	Unheated buildings where condensation may occur, e. g. depots, sport halls.
C3	Medium	Urban and industrial atmospheres, moderate sulphur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e. g. food-processing plants, laundries, breweries and dairies.
C4	High	Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ship- and boatyards.
C5-I	Very high (in-dustrial)	Industrial areas with high humidity and aggressive atmosphere.	Building or areas with almost permanent condensation and with high pollution.
C5-M	Very high (marine)	Coastal and offshore areas with high salinity.	Building or areas with almost permanent condensation and with high pollution.



Any distribution of forces, where the internal forces (bolt forces) are in equilibrium with the external forces in such a way that nowhere is the internal load-carrying resistance (the design resistance of the bolts) exceeded, gives a lower bound to the design resistance of the connection.

This principle is only valid if sufficient deformation capacity is available. In bolted connections this capacity can be assured by designing the bolts such that they are not the controlling item of the strength of the connection:

- In shear and bearing: let bearing be decisive, because the deformation capacity in bearing of the plate is much bigger than the deformation capacity in shear of the bolt.
- In tension: let yielding of the plates in bending be decisive rather than rupture of the bolt.