# CEN/TS 19100-3

## in-plane loaded elements and joints

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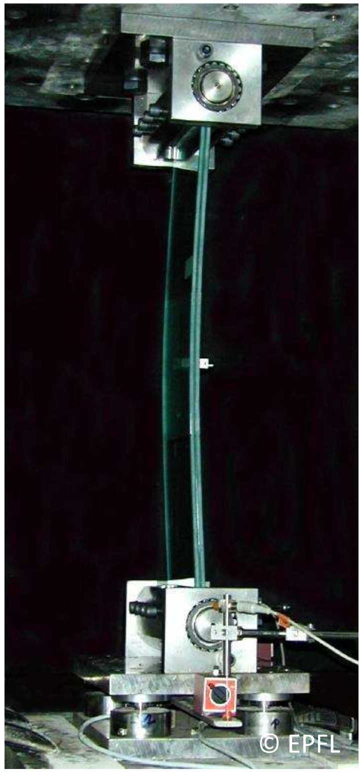
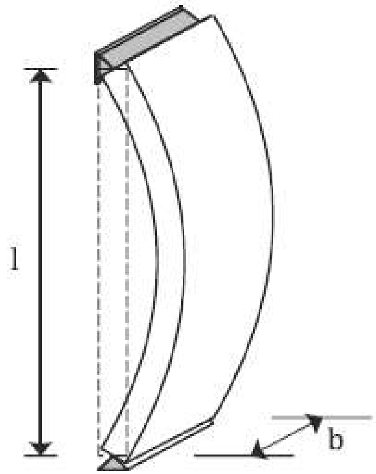
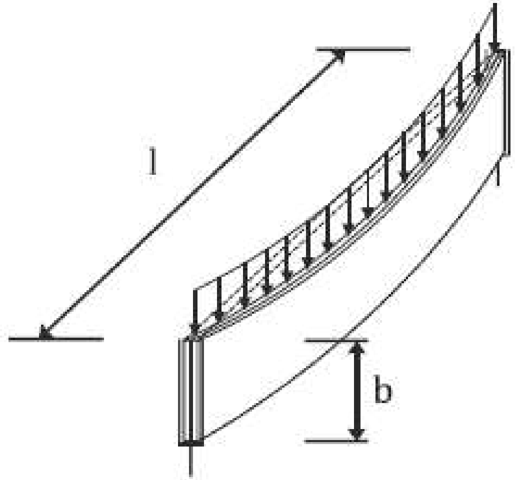
## in-plane loaded elements








column buckling

lateral torsional buckling

## in-plane loaded elements



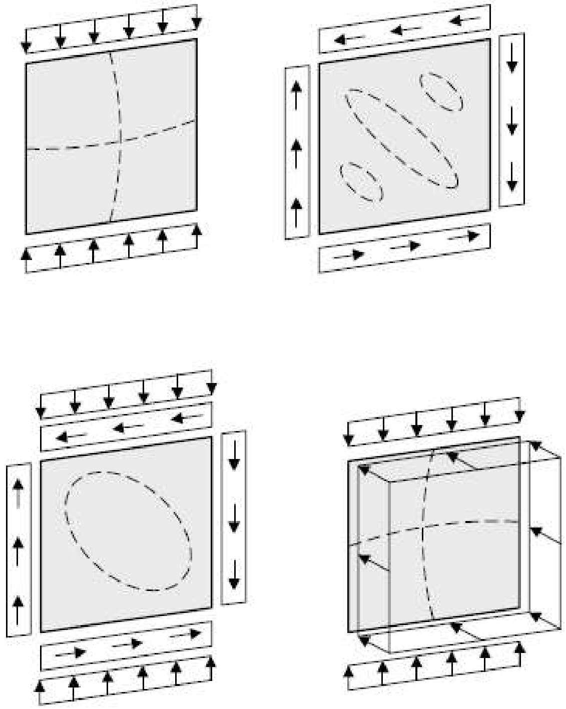
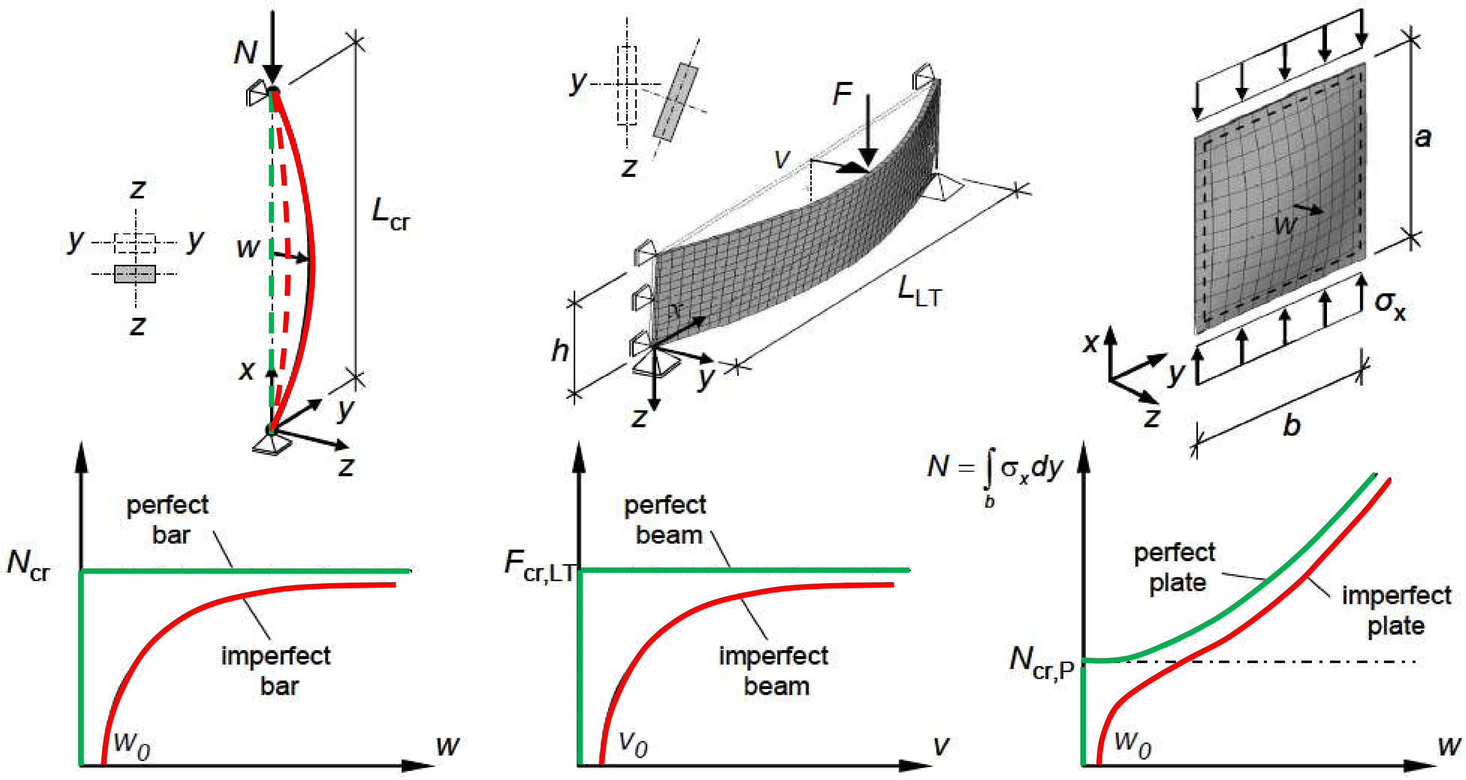


plate buckling

# in-plane loaded elements




(a) column buckling (b) lateral torsional buckling (c) plate buckling

in-plane loaded elements

- ✓ structural analysis
  - second order effects

$$\alpha_{cr} = \frac{F_{cr}}{F_{Ed}} \leq 10$$

  - imperfections
    - equivalent geometrical imperfection
    - basic imperfection (ULS and SLS)*

$$e_0 = \sqrt{e_{0,length}^2 + e_{0,installation}^2}$$

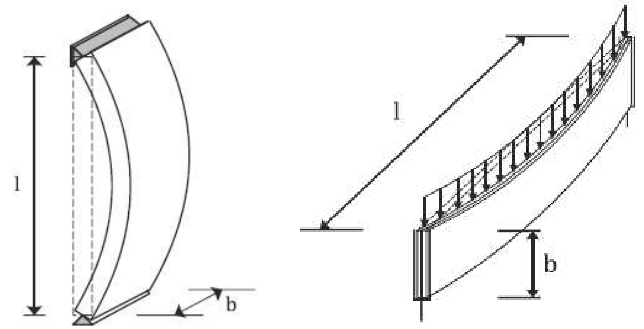



Table 7.1 (NDP) — Imperfection parts for buckling cases

| Type | $l_0$ | both for mono and laminated glass panes $e_{0,length}$ [a] | $e_{0,installation}$ [b,c,d] |
|---|---|---|---|
| **Flexural buckling and plate buckling** | Distance of inflexion points in the relevant critical mode in direction of the applied load | $l_0/333$ | $h_e/2$ |
| **Lateral torsional buckling** | Distance of inflexion points at the edge in compression in the relevant critical mode | $l_0/450$ | $h_e/2$ |
| **Shear buckling** | Longest diagonal | $l_0/1000$ | $h_e/5$ |

[a] $e_{0,length}$ should be applied at the location where the curvature of the relevant critical mode gets its maximum.

[b] $e_{0,installation}$ may be applied at the location where the installation eccentricity occurs. Alternatively, for simplification reasons, it may be applied at the same location as the one of $e_{0,length}$.

[c] For perpendicular to the glass plane, straight edges over the thickness of the laminate, the value for $h_e$ is: $h_e = h_{tot}$. For stepped edges or other edge geometries the value of he can be determined individually.

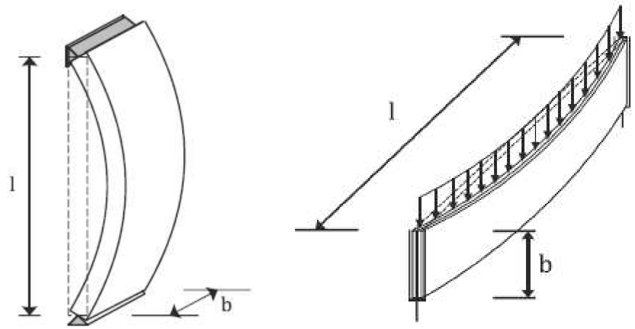
[d] If $e_{0,installation}$ is recorded on site it may be reduced to the measured value, but not smaller than 3mm. This requires care in execution and control.

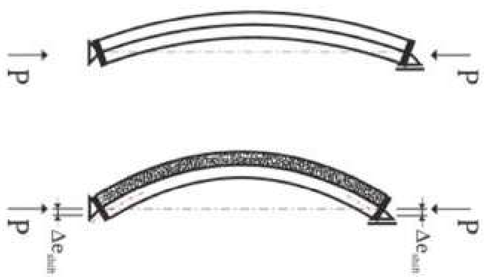
in-plane loaded elements

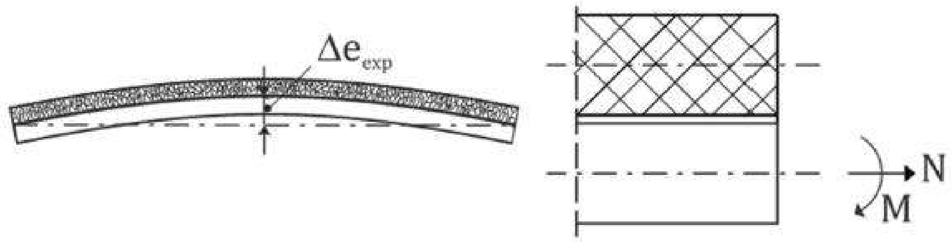
✓ structural analysis
- second order effects

$$\alpha_{cr} = \frac{F_{cr}}{F_{Ed}} \leq 10$$

- imperfections
  - equivalent geometrical imperfection
  - basic imperfection (ULS and SLS)*
  - shift after fracture laminated glass and/or TTG ply

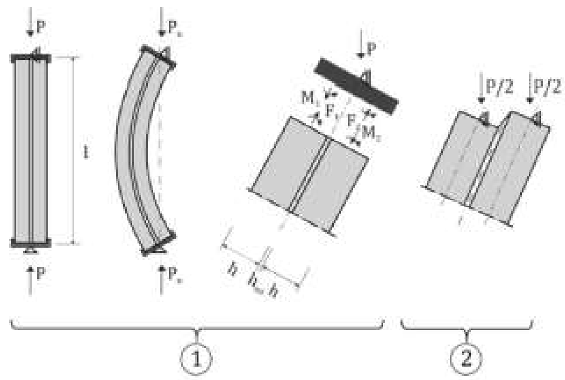


in-plane loaded elements

✓ points of attention
- interlayer properties (level 0, 1, 2)
- temperature and long-term effects
- detailing
  - load introduction
    - continuous vs concentrated
  - avoid peak stresses
    - durable detailing
  - avoid hard contact
    - deformations
    - tolerances (manufacturing and erecting
  - slip restraint




| Item | Description |
|---|---|
| 1 | with slip restraint |
| 2 | without slip restraint |

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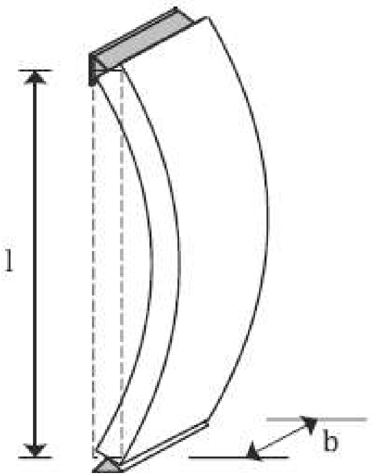
## in-plane loaded elements

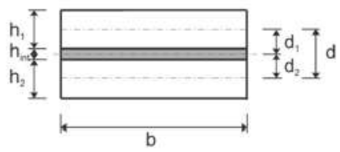
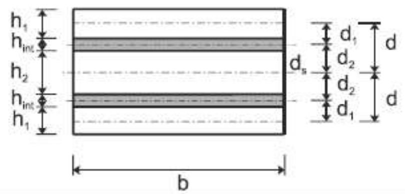
✓ critical buckling load $N_{cr}$




$$N_{cr} = \frac{\pi^2 E I_{z,eff}}{L^2}$$

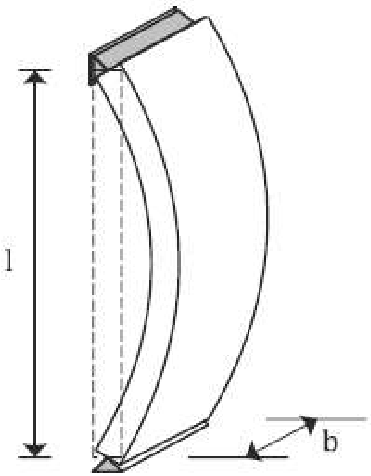
$$I_{z,eff} = \frac{\sum I_i}{1 - \frac{\Psi \cdot \beta \cdot K_s}{\left(\frac{\pi}{L}\right)^2 + \alpha^2}}$$

**Table B.1 – Cross section parameters for effective inertia calculation**

| |  |  |
|---|---|---|
| $K_s$ | $\frac{G_L}{t} B$ | $\frac{G_L(t)}{t} B$ |
| $\alpha^2$ | $\frac{K_s}{E}\left(\frac{(z_1+z_2)^2}{I_1+I_2}+\frac{1}{A_1}+\frac{1}{A_2}\right)$ | $\frac{K_s}{E}\left(\frac{2(z_1+z_2)^2}{2I_1+I_2}+\frac{1}{A_1}\right)$ |
| $\beta$ | $\frac{(z_1+z_2)}{E(I_1+I_2)}$ | $\frac{(z_1+z_2)}{E(2I_1+I_2)}$ |
| $\Psi$ | $(z_1+z_2)$ | $2 \cdot (z_1+z_2) = 2 \cdot z$ |

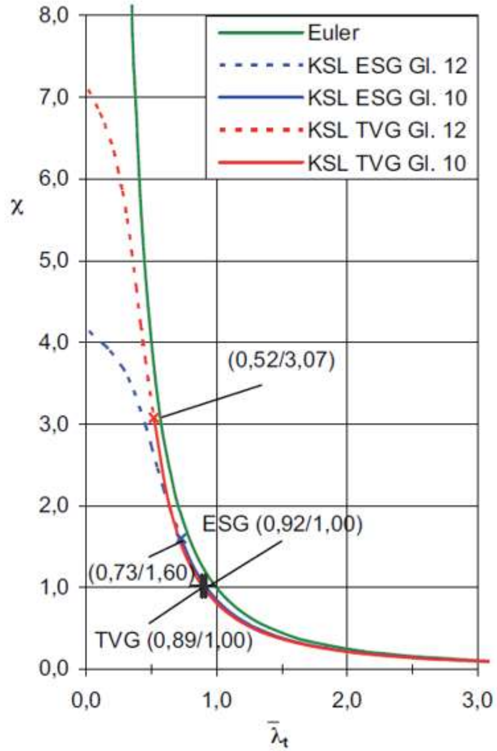
in-plane loaded elements

✓ critical buckling load $N_{cr}$



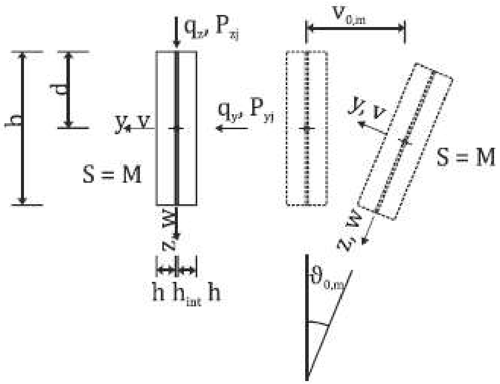

$$N_{cr} = \frac{\pi^2 E I_{z,eff}}{L^2}$$

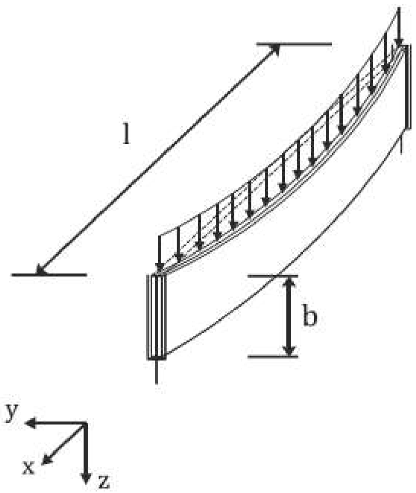
slenderness ratio λ
reduction factor χ = f(λ)
buckling strength $N_{b,Rd}$



# in-plane loaded elements

✓ critical bending moment $M_{cr}$




$$M_{cr,LT} = C_1 \frac{\pi^2 E I_{z,eff}}{L^2} \left[ \sqrt{(C_2 z_p)^2 + \left(\frac{G I_{t,eff}\, L^2}{\pi^2 E I_{z,eff}}\right)} + (C_2 z_p) \right]$$

**Table A.1 — Values C1 and C2**

| Bending moment | C1 | C2 |
|---|---|---|
| Constant | 1.0 | - |
| Linear (zero at midspan) | 2.7 | 0.0 |
| Parabolic (zero at both extremities) | 1.13 | 0.46 |
| Triangular (zero at both extremities and maximum at mid span) | 1.36 | 0.55 |

$$I_{T,eff} = \frac{2}{3} B\, h^3 + 2B\, h(h_L + h)^2 \left(1 - \frac{\tanh\left(\lambda_T \frac{B}{2}\right)}{\lambda_T \frac{B}{2}}\right)$$

$$\lambda_T = \sqrt{\frac{2\, G_L}{G\, h_L h}}$$