TALAT Lecture 2301

Design of Members

Local Buckling

Example 3.1 Deflection of class 4 cross section

5 pages

Advanced Level

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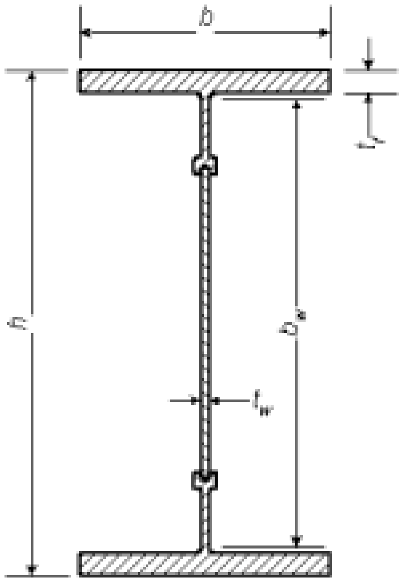
Example 3.1 Deflection of class 4 cross section

Dimensions and material properties



Total height: $h := 350 \cdot mm$

Flange depth: $b := 110 \cdot mm$

Flange thickness: $t_f := 10 \cdot mm$

Web thickness: $t_w := 5 \cdot mm$

Span: $L := 7.2 \cdot m$

Width of web plate:

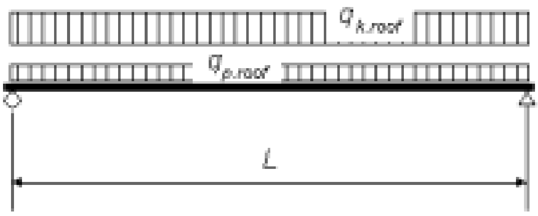
$b_w := h - 2 \cdot t_f$ $b_w = 330 \, mm$

[1] Table 3.2b Alloy: **EN AW-6082 T6** EP/O t > 5 mm

$f_{0.2} := 260 \cdot MPa$ $E := 70000 \cdot MPa$

$f_o := f_{0.2}$

Distributed loads



Characteristic values

Permanent load $q_{p.roof} := 2.0 \cdot kN \cdot m^{-1}$

Snow load $q_{k.roof} := 4.0 \cdot kN \cdot m^{-1}$

S.I. units $kN \equiv 1000 \cdot newton$ $kNm \equiv kN \cdot m$ $MPa \equiv 1000000 \cdot Pa$

References

[1] ENV 1999-1-1. Eurocode 9 - Design of aluminium structures - Part 1-1: General rules. 1997
[2] ENV 1991-1. Eurocode 1 - Basis of design and actions on structures - Part 1: Basis of design. 1994

Comment: To calculate the deflections a fictitious second moment of area I_{fic} according to [1] 4.2.4 is used. The second moment of area of the effective cross section in the ultimate limit state I_{eff} with allowance for local buckling is then needed.

[1] (4.2) $$I_{fic} := I_{gr} - \frac{\sigma_{gr}}{f_o} \cdot \left(I_{gr} - I_{eff}\right)$$

Local buckling

a) Web

[1] Tab. 5.1
Heat treated, *welded web*

$g := 0.4$

$\varepsilon := \sqrt{\frac{250 \cdot MPa}{f_o}}$ $\varepsilon = 0.981$

$\beta_w := g \cdot \frac{b_w}{t_w}$ $\beta_w = 26.4$

$\beta_{3w} := 18 \cdot \varepsilon$ $\beta_{3w} = 17.65$

$class_w := if(\beta_w > \beta_{3w}, 4, 3)$ $class_w = 4$

[1] 5.4.5 Reduction factor:

$\rho_{cw} := if\left[\frac{\beta_w}{\varepsilon} \le 18, 1.0, \frac{29}{\left(\frac{\beta_w}{\varepsilon}\right)} - \frac{198}{\left(\frac{\beta_w}{\varepsilon}\right)^2}\right]$

$t_{w.ef} := if(class_w \ge 4, t_w \cdot \rho_{cw}, t_w)$

$\rho_{cw} = 0.804$ $t_{w.ef} = 4.0 \circ mm$

b) Flanges

[1] 5.4.3
Heat treated
unwelded flange

$\psi := 1$ $g := 1$

$\beta_f := g \cdot \frac{b - t_w}{2 \cdot t_f}$ $\beta_f = 5.25$

$\beta_{3f} := 6 \cdot \varepsilon$ $\beta_{3f} = 5.883$

[1] Tab. 5.1 $class_f := if(\beta_f > \beta_{3f}, 4, 3)$ $class_f = 3$

[1] 5.4.5 Reductionfactor: $class_f = 3$ $\rho_{cf} := 1$ $t_{f.ef} := t_f$

Classification of the total cross-section: $class := if(class_f > class_w, class_f, class_w)$ $class = 4$

c) Flange induced buckling

[1] 5.12.9 Elastic moment resistance utilized $k := 0.55$ $f_{of} := f_o$

[1] (5.115) $LS = \frac{b_w}{t_w} = 66$ $RS = \frac{k \cdot E}{f_{of}} \cdot \sqrt{\frac{b_w \cdot t_w}{b \cdot t_f}} = 181.4$ $LS < RS$ OK!

Bending stiffness

[1] 5.6.2 Elastic modulus of gross cross section W_{el}:

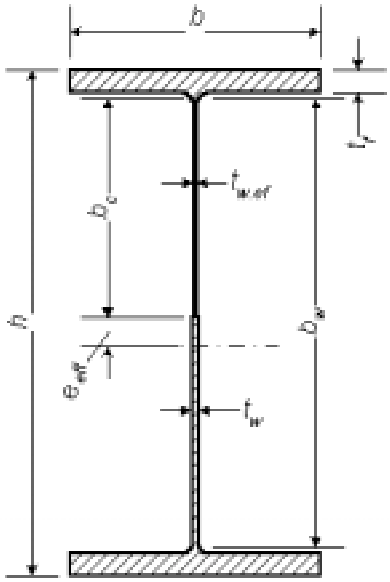
$A_{gr} := 2 \cdot b \cdot t_f + (h - 2 \cdot t_f) \cdot t_w$ $A_{gr} = 3.85 \cdot 10^3 \circ mm^2$

$I_{gr} := \frac{1}{12} \cdot \left[b \cdot h^3 - (b - t_w) \cdot (h - 2 \cdot t_f)^3\right]$ $I_{gr} = 7.857 \cdot 10^7 \circ mm^4$

$W_{el} := \frac{I_{gr} \cdot 2}{h}$ $W_{el} = 4.49 \cdot 10^5 \circ mm^3$

h

Second moment of area of the effective cross section I_{eff}:



$t_f = 10 \cdot mm$ $\quad$ $t_{f.ef} = 10 \cdot mm$

As $t_{f.ef} = t_f$ then $\quad$ $b_c := \frac{b_w}{2}$ $\quad$ $b_c = 165 \cdot mm$

$t_w = 5 \cdot mm$ $\quad$ $t_{w.ef} = 4 \cdot mm$

Allowing for local buckling:

$$A_{eff} := A_{gr} - b \cdot (t_f - t_{f.ef}) - b_c \cdot (t_w - t_{w.ef})$$

$$A_{eff} = 3.688 \cdot 10^3 \cdot mm^2$$

Shift of gravity centre:

$$e_{eff} := \left[b \cdot (t_f - t_{f.ef}) \cdot \left(\frac{h}{2} - \frac{t_f}{2} \right) + \frac{b_c^{\,2}}{2} \cdot (t_w - t_{w.ef}) \right] \cdot \frac{1}{A_{eff}} \qquad e_{eff} = 3.617 \cdot mm$$

Second moment of area with respect to centre of gross cross section:

$$I_{eff} := I_{gr} - b \cdot (t_f - t_{f.ef}) \cdot \left(\frac{h}{2} - \frac{t_f}{2} \right)^2 - \frac{b_c^{\,3}}{3} \cdot (t_w - t_{w.ef}) \qquad I_{eff} = 7.71 \cdot 10^7 \cdot mm^4$$

Second moment of area with respect to centre of effective cross section:

$$I_{eff} := I_{eff} - e_{eff}^{\,2} \cdot A_{eff} \qquad I_{eff} = 7.706 \cdot 10^7 \cdot mm^4$$

[1] 4.2.4 (2) $\quad$ Allowing for a reduced stress level I_{fic} may be used constant along the beam.

[2] 9.5.2 b) $\quad$ Frequent load combination, serviceability limit state, snow load

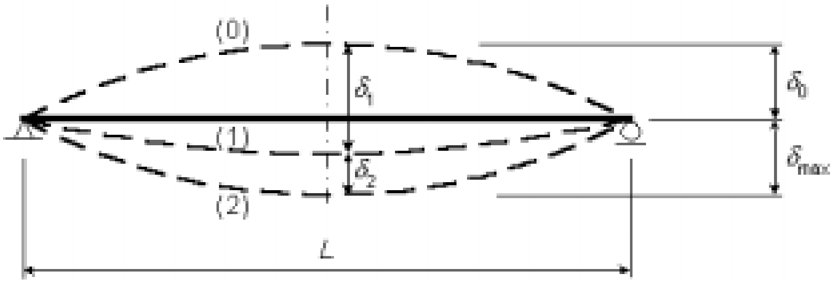
[2] Table 9.3 $\quad$ $\psi_{11} := 0.2 \qquad \psi_{11} = 0.2$

$$M_{Ed} := (q_{p.roof} + \psi_{11} \cdot q_{k.roof}) \cdot \frac{L^2}{8} \qquad M_{Ed} = 18.1 \cdot kNm$$

[1] 4.2.4 (2) $\quad$ $\sigma_{gr} := \frac{M_{Ed}}{W_{el}} \qquad \sigma_{gr} = 40.4 \cdot MPa$

[1] (4.2) $\quad$ $I_{fic} := I_{gr} - \frac{\sigma_{gr}}{f_o} \cdot (I_{gr} - I_{eff}) \qquad I_{fic} = 7.834 \cdot 10^7 \cdot mm^4$

Deflections



$\delta_1 := \frac{5 \cdot q_{p.roof} \cdot L^4}{384 \cdot E \cdot I_{fic}}$ $\qquad q_{p.roof} = 2 \circ kN \cdot m^{-1}$ $\qquad \delta_1 = 12.8 \circ mm$

$\delta_2 := \psi_{11} \cdot \frac{5 \cdot q_{k.roof} \cdot L^4}{384 \cdot E \cdot I_{fic}}$ $\qquad q_{k.roof} = 4 \circ kN \cdot m^{-1}$ $\qquad \delta_2 = 5.1 \circ mm$

No pre-camber $\qquad \delta_0 := 0 \cdot mm$

[1] (4.1) $\qquad \delta_{max} := \delta_1 + \delta_2 - \delta_0$ $\qquad \delta_{max} = 17.9 \circ mm$

[1] 4.2.3 $\qquad \delta_{limit} := \frac{L}{360}$ for beams carrying plaster or other brittle finish $\qquad \delta_{limit} = 20 \circ mm$

$check := if\left(\delta_{max} \le \delta_{limit}, \text{"OK!"}, \text{"Not OK!"}\right)$ $\qquad check = \text{"OK!"}$