TALAT Lecture 2301

Design of Members

Bending Moment

Example 4.4 : Bending moment resistance of welded hollow section with outstands. Class 4 cross section

10 pages

Advanced Level

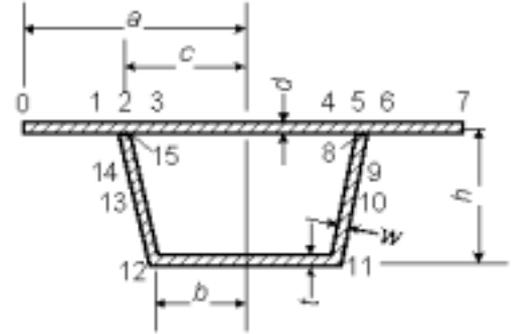**prepared by Torsten Höglund, Royal Institute of Technology, Stockholm**

Example 4.4. Bending moment resistance of welded hollow section with outstands. Class 4 cross section

Half top flange $a := 200 \cdot mm$ Half hollow width $c := 96 \cdot mm$ $f_o := 200 \cdot MPa$

Half bottom flange $b := 96 \cdot mm$ Width of HAZ $haz := 30 \cdot mm$ $\gamma_{MI} := 1.1$

Section dept $h := 99 \cdot mm$ HAZ reduction $\rho_{haz} := 0.8$ $MPa \equiv 10^6 \cdot Pa$

Flange thickness $d := 6 \cdot mm$

Web thickness $w := 8 \cdot mm$ $bz := c - \dfrac{haz}{\sqrt{(c-b)^2 + h^2}} \cdot (c-b)$

Bottom flange t. $t := 8 \cdot mm$

Type of element
 - Internal element: $T = 0$ $hz := \dfrac{haz}{\sqrt{(c-b)^2 + h^2}} \cdot h$
 - Outstand: $T > 0$

$o := 0 \cdot mm$

Nodes, co-ordinates (y, z), thickness (t) and types (T)

$$
i := \begin{bmatrix} 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \end{bmatrix}
\quad
y := \begin{bmatrix} -a \\ -c - haz \\ -c \\ -c + haz \\ c - haz \\ c \\ c + haz \\ a \\ c \\ bz \\ 0.5 \cdot (c + b) \\ b \\ -b \\ -0.5 \cdot (c + b) \\ -bz \\ -c \end{bmatrix}
\quad
z := \begin{bmatrix} o \\ o \\ o \\ o \\ o \\ o \\ o \\ o \\ o \\ -hz \\ -0.5 \cdot h \\ -h \\ -h \\ -0.5 \cdot h \\ -hz \\ o \end{bmatrix}
\quad
t := \begin{bmatrix} o \\ d \\ d \\ d \\ d \\ d \\ d \\ d \\ o \\ w \\ w \\ w \\ t \\ w \\ w \\ w \end{bmatrix}
\quad
T := \begin{bmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}
$$

Comments:
Node 10 and 13
indicate shift in neutral axis.
Element 1-2, 2-3, 4-5, 5-6, 8-9
*and 14-15 define HAZs.*

This solution of the example is comprehensive because:
1. Calculations are shown in every detail
2. It covers all classes of cross section
3. The possibility to increase the effective thickness for elements not fully stressed is shown. The iteration procedure is then mandatory. However, in this example, the result is almost exactly the same as if a simplified method was used, that's because there is no reduction of the web thickness due to local buckling.

The beam is composed by two extrusions. The weld is close to the neutral axis why HAZ softening does not influence the moment resistance.

Nodes $i := 1 .. rows(y) - 1$ $rows(y) = 16$

Area of cross section elements $dA_i := \left[t_i \cdot \sqrt{\left(y_i - y_{i-1}\right)^2 + \left(z_i - z_{i-1}\right)^2} \right]$
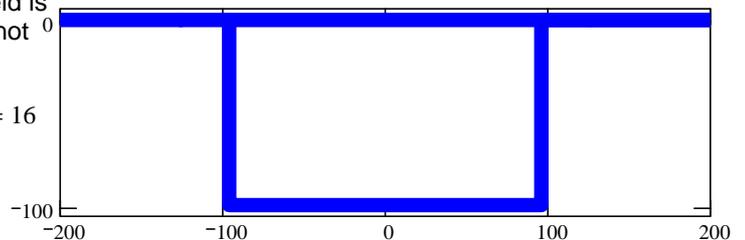
| Cross section area | $A := \displaystyle\sum_{i=1}^{rows(y)-1} dA_i$ | $A = 5.52 \cdot 10^3 \cdot mm^2$ |

| First moment of area Gravity centre | $S_y := \displaystyle\sum_{i=1}^{rows(y)-1} \left(z_i + z_{i-1}\right) \cdot \frac{dA_i}{2}$ | $z_{gc} := \dfrac{S_y}{A}$ |

$$z_{gc} = -41.752 \cdot mm$$

| Second moment of area | $I_y := \displaystyle\sum_{i=1}^{rows(y)-1} \left[\left(z_i\right)^2 + \left(z_{i-1}\right)^2 + z_i \cdot z_{i-1} \right] \cdot \frac{dA_i}{3}$ | $z_{gc.gr} := z_{gc}$ |

$$I_y := I_y - A \cdot z_{gc}^2$$

$$I_{y.gr} := I_y \qquad I_y = 1.061 \cdot 10^7 \cdot mm^4$$

| Elastic section modulus | $W_{el} := if\left(max\left(z - z_{gc}\right) > \left| min\left(z - z_{gc}\right) \right|, \dfrac{I_y}{max\left(z - z_{gc}\right)}, \dfrac{I_y}{\left| min\left(z - z_{gc}\right) \right|} \right)$ |

$$W_{el} = 1.853 \cdot 10^5 \cdot mm^3$$

| Torsion constant for open parts | $I_{tu} := \displaystyle\sum_{i=1}^{rows(y)-1} dA_i \cdot \frac{\left(t_i\right)^2}{3}$ | $I_{tu} = 9.536 \cdot 10^4 \cdot mm^4$ |

Hollow part, (nodes 2, 5, 11, 12 and 15)

$$y_h := \begin{bmatrix} y_2 \\ y_5 \\ y_{11} \\ y_{12} \\ y_{15} \end{bmatrix} \qquad y_h = \begin{bmatrix} -96 \\ 96 \\ 96 \\ -96 \\ -96 \end{bmatrix} \cdot mm \qquad z_h := \begin{bmatrix} z_2 \\ z_5 \\ z_{11} \\ z_{12} \\ z_{15} \end{bmatrix} \qquad z_h = \begin{bmatrix} 0 \\ 0 \\ -99 \\ -99 \\ 0 \end{bmatrix} \cdot mm \qquad t_h := \begin{bmatrix} t_1 \\ t_4 \\ t_{11} \\ t_{12} \\ t_{14} \end{bmatrix} \qquad t_h = \begin{bmatrix} 6 \\ 6 \\ 8 \\ 8 \\ 8 \end{bmatrix} \cdot mm$$

| Area within mid-line | $A_{tu} := \displaystyle\sum_{i=1}^{rows(y_h)-1} 0.5 \cdot \left(y_{h_i} - y_{h_{i-1}}\right) \cdot \left(z_{h_i} + z_{h_{i-1}}\right)$ | $A_{tu} = 1.901 \cdot 10^4 \cdot mm^2$ |

| Sum of l/t | $Dn := \displaystyle\sum_{i=1}^{rows(y_h)-1} if\left[t_i > 0, \dfrac{\sqrt{\left(y_{h_i} - y_{h_{i-1}}\right)^2 + \left(z_{h_i} - z_{h_{i-1}}\right)^2}}{t_{h_i}}, 10^{22} \right]$ | $Dn = 80.75$ |

| Torsion constant for closed part | $I_t := \dfrac{4 \cdot A_{tu}^2}{Dn}$ | $I_t = 1.79 \cdot 10^7 \cdot mm^4$ |

| Torsion constant whole section | $I_t := I_t + I_{tu}$ | $I_t = 1.799 \cdot 10^7 \cdot mm^4$ |

| Torsion resistance | $W_v := 2 \cdot A_{tu} \cdot min\left(t_h\right)$ | $min\left(t_h\right) = 6 \cdot mm$ | $W_v = 2.281 \cdot 10^5 \cdot mm^3$ |

$$z_{gc} = -41.752 \cdot mm$$

Effective cross section First iteration

5.4.3 (1) $\psi_i := 1 \qquad j := 9..11 \qquad \psi_j := \dfrac{z_8 - z_{gc}}{z_{11} - z_{gc}} \qquad \psi_{j+4} := \psi_j \qquad z_{d_i} := \left| z_i - z_{gc} \right|$

$max_z := max\left(z_d\right)$

(5.7 or 5.8) $g_i := if\left(\psi_i > -1, 0.7 + 0.30 \cdot \psi_i, \dfrac{0.8}{1 - \psi_i}\right)$ Outstand Figure 5.2 $g_i := if\left(T_i > 0, 1, g_i\right)$

5.4.3 (1) c) $k := 1..2 \qquad \beta_k := \dfrac{y_2 - y_0 - 0.5 \cdot t_{13}}{t_2} \qquad \beta_{k+5} := \beta_k \qquad y_2 = -96 \bullet mm$

$y_0 = -200 \bullet mm$

$\dfrac{y_2 - y_0}{t_2} = 17.333$

$l := 3..5 \qquad \beta_l := \dfrac{y_5 - y_2 - t_{13}}{t_4}$

$\beta_j := if\left[t_{11} > 0, g_j \cdot \dfrac{\sqrt{\left(y_{11} - y_8\right)^2 + \left(z_{11} - z_8\right)^2}}{t_{11}}, 1\right] \qquad \beta_{j+4} := \beta_j$

5.4.4 (5) $\varepsilon_o := \sqrt{\dfrac{250 \cdot MPa}{f_o}} \qquad \varepsilon_i := \varepsilon_o \cdot \sqrt{\dfrac{max_z}{\left| z_{gc} \right|}} \qquad \varepsilon_i := if\left[\left(z_i \geq z_{gc}\right) \cdot \left(z_{i-1} \geq z_{gc}\right), \varepsilon_i, 99\right] \qquad \varepsilon_{\bar{o}} \; 1.118$

5.4.5 (3)
a) or c)
non heat
treated, welded $\rho_{c_i} := if\left[T_i > 0, if\left[\dfrac{\beta_i}{\varepsilon_i} > 4, 8 \cdot \dfrac{\varepsilon_i}{\beta_i} - 16 \cdot \left(\dfrac{\varepsilon_i}{\beta_i}\right)^2, 1.0\right], if\left[\dfrac{\beta_i}{\varepsilon_i} > 15, 25 \cdot \dfrac{\varepsilon_i}{\beta_i} - 150 \cdot \left(\dfrac{\varepsilon_i}{\beta_i}\right)^2, 1.0\right]\right]$

Effective thickness $t_{eff} := \overrightarrow{\left(\rho_c \cdot t\right)}$

Heat Affected Zone

Flange $t_{haz.f} := \rho_{haz} \cdot t_2 \qquad t_{haz.f} = 4.8 \bullet mm$

Web $t_{haz.w} := \rho_{haz} \cdot t_9 \qquad t_{haz.w} = 6.4 \bullet mm$

$n := 2..3 \qquad t_{eff_n} := if\left(t_{eff_n} > t_{haz.f}, t_{haz.f}, t_{eff_n}\right) \qquad t_{eff_{8-n}} := t_{eff_n}$

$t_{eff_9} := if\left(t_{eff_9} > t_{haz.w}, t_{haz.w}, t_{eff_9}\right) \qquad t_{eff_{15}} := t_{eff_9}$

Comment:
ε_i was given a large value (99)
for elements entirely on
the tension side

$\psi_i =$	$g_i =$	$\beta_i =$	$\varepsilon_i =$	$\dfrac{\beta_i}{\varepsilon_i} =$	$\rho_{c_i} =$	$\dfrac{t_{eff_i}}{mm} =$
1	1	16.667	1.309	12.731	0.53	3.178
1	1	16.667	1.309	12.731	0.53	3.178
1	1	30.667	1.309	23.425	0.794	4.763
1	1	30.667	1.309	23.425	0.794	4.763
1	1	30.667	1.309	23.425	0.794	4.763
1	1	16.667	1.309	12.731	0.53	3.178
1	1	16.667	1.309	12.731	0.53	3.178
1	1	0	1.309	0	1	0
-0.729	0.481	5.955	1.309	4.549	1	6.4
-0.729	0.481	5.955	99	0.06	1	8
-0.729	0.481	5.955	99	0.06	1	8
1	1	0	99	0	1	8
-0.729	0.481	5.955	99	0.06	1	8
-0.729	0.481	5.955	99	0.06	1	8
-0.729	0.481	5.955	1.309	4.549	1	6.4

Area of effective thickness elements $dA_i := \overrightarrow{\left[t_{eff_i} \cdot \sqrt{\left(y_i - y_{i-1}\right)^2 + \left(z_i - z_{i-1}\right)^2}\right]}$

Cross section area	$A_{eff} := \sum\limits_{i=1}^{rows(y)-1} dA_i$	$A = 5.52 \cdot 10^3 \circ mm^2$

$A_{eff} = 4.6 \cdot 10^3 \circ mm^2$

First moment of area

Gravity centre

$$S_y := \sum\limits_{i=1}^{rows(y)-1} (z_i + z_{i-1}) \cdot \frac{dA_i}{2}$$

$z_{gc} := \dfrac{S_y}{A_{eff}}$ $z_{gc} = -49.794 \circ mm$

Effective cross section Second iteration

Node 10 and 13 is moved to the neutral axis from the first iteration

$z_{10} := z_{gc} + 0.01 \cdot mm$ $z_{13} := z_{gc} + 0.01 \cdot mm$

$$y_{10} := y_5 - \frac{z_{10}}{z_{11}} \cdot (y_5 - y_{11})$$ $y_{13} := -y_{10}$

5.4.3 (1)

$\psi_i := 1$ $j := 9 .. 11$ $\psi_j := \dfrac{z_8 - z_{gc}}{z_{11} - z_{gc}}$ $\psi_{j+4} := \psi_j$

$z_{d_i} := |z_i - z_{gc}|$

$max_z := max(z_d)$

(5.7 or 5.8)

$g_i := if\left(\psi_i > -1, 0.7 + 0.30 \cdot \psi_i, \dfrac{0.8}{1 - \psi_i}\right)$ Outstand Figure 5.2 $g_i := if(T_i > 0, 1, g_i)$

5.4.3 (1) c)

$k := 1 .. 2$ $\beta_k := \dfrac{y_2 - y_0 - 0.5 \cdot t_{13}}{t_2}$ $\beta_{k+5} := \beta_k$ $l := 3 .. 5$ $\beta_l := \dfrac{y_5 - y_2 - t_{13}}{t_4}$

$$\beta_j := if\left[t_{11} > 0, g_j \cdot \frac{\sqrt{(y_{11} - y_8)^2 + (z_{11} - z_8)^2}}{t_{11}}, 1\right]$$ $\beta_{j+4} := \beta_j$

5.4.4 (5)

$\varepsilon_o := \sqrt{\dfrac{250 \cdot MPa}{f_o}}$ $\varepsilon_i := \varepsilon_o \cdot \sqrt{\dfrac{max_z}{|z_{gc}|}}$ $\varepsilon_i := if\left[(z_i \geq z_{gc}) \cdot (z_{i-1} \geq z_{gc}), \varepsilon_i, 99\right]$ $\varepsilon_{\overline{o}} 1.118$

5.4.5 (3) a) or c) non heat treated, welded

$$\rho_{c_i} := if\left[T_i > 0, if\left[\frac{\beta_i}{\varepsilon_i} > 4, 8 \cdot \frac{\varepsilon_i}{\beta_i} - 16 \cdot \left(\frac{\varepsilon_i}{\beta_i}\right)^2, 1.0\right], if\left[\frac{\beta_i}{\varepsilon_i} > 15, 25 \cdot \frac{\varepsilon_i}{\beta_i} - 150 \cdot \left(\frac{\varepsilon_i}{\beta_i}\right)^2, 1.0\right]\right]$$

Effective thickness

$t_{eff} := \overrightarrow{(\rho_c t)}$

Heat Affected Zone

$$t_{eff_n} := if\left(t_{eff_n} > t_{haz.f}, t_{haz.f}, t_{eff_n}\right) \qquad t_{eff_{8-n}} := t_{eff_n}$$

$$t_{eff_9} := if\left(t_{eff_9} > t_{haz.w}, t_{haz.w}, t_{eff_9}\right) \qquad t_{eff_{15}} := t_{eff_9}$$

$i =$	$T_i =$	$\psi_i =$	$g_i =$	$\beta_i =$	$\varepsilon_i =$	$\dfrac{\beta_i}{\varepsilon_i} =$	$\rho_{c_i} =$	$\dfrac{t_{eff_i}}{mm} =$
1	1	1	1	16.667	1.118	14.907	0.465	2.788
2	1	1	1	16.667	1.118	14.907	0.465	2.788
3	0	1	1	30.667	1.118	27.429	0.712	4.272
4	0	1	1	30.667	1.118	27.429	0.712	4.272
5	0	1	1	30.667	1.118	27.429	0.712	4.272
6	1	1	1	16.667	1.118	14.907	0.465	2.788
7	1	1	1	16.667	1.118	14.907	0.465	2.788
8	0	1	1	0	1.118	0	1	0
9	0	-1.012	0.398	4.921	1.118	4.401	1	6.4
10	0	-1.012	0.398	4.921	1.118	4.401	1	8
11	0	-1.012	0.398	4.921	99	0.05	1	8
12	0	1	1	0	99	0	1	8
13	0	-1.012	0.398	4.921	99	0.05	1	8
14	0	-1.012	0.398	4.921	1.118	4.401	1	8
15	0	-1.012	0.398	4.921	1.118	4.401	1	6.4

Max slenderness - Internal elements

$$\beta_{e_i} := if\left(T_i > 0, 0, \frac{\beta_i}{\varepsilon_i}\right)$$

$$\beta_{Imax} := max\left(\beta_e\right)$$

$$\beta_{Imax} = 27.429$$

Max slenderness - Outstands

$$\beta_{e_i} := if\left(T_i > 0, \frac{\beta_i}{\varepsilon_i}, 0\right)$$

$$\beta_{Omax} := max\left(\beta_e\right)$$

$$\beta_{Omax} = 14.907$$

Cross section class (5.15)

$$class_I := if\left(\beta_{Imax} \le 7, 1, if\left(\beta_{Imax} \le 11, 2, if\left(\beta_{Imax} \le 15, 3, 4\right)\right)\right) \qquad class_I = 4$$

$$class_O := if\left(\beta_{Omax} \le 2, 1, if\left(\beta_{Omax} \le 3, 2, if\left(\beta_{Omax} \le 4, 3, 4\right)\right)\right) \qquad class_O = 4$$

$$class := if\left(class_I > class_O, class_I, class_O\right) \qquad class = 4$$

Area of effective thickness elements

$$dA_i := \left[t_{eff_i} \cdot \sqrt{\left(y_i - y_{i-1}\right)^2 + \left(z_i - z_{i-1}\right)^2}\right]$$

Area of effective cross section

$$A_{eff} := \sum_{i=1}^{rows(y)-1} dA_i$$

$$A = 5.52 \cdot 10^3 \cdot mm^2$$

$$A_{eff} = 4.424 \cdot 10^3 \cdot mm^2$$

First moment of area. Gravity centre

$$S_y := \sum_{i=1}^{rows(y)-1} \left(z_i + z_{i-1}\right) \cdot \frac{dA_i}{2}$$

$$z_{gc} := \frac{S_y}{A_{eff}}$$

$$z_{gc} = -51.768 \cdot mm$$

| Second moment of area of effective cross section | $$I_y := \sum_{i=1}^{rows(y)-1} \left[(z_i)^2 + (z_{i-1})^2 + z_i \cdot z_{i-1} \right] \cdot \frac{dA_i}{3}$$ | $$I_{eff} := I_y - A_{eff} \cdot z_{gc}^2$$ |
| | | $$I_{eff} = 8.344 \cdot 10^6 \, \text{·} mm^4$$ |

| Section modulus | $$z_{d_i} := \left| z_i - z_{gc} \right|$$ | $$max_{z.eff} := max(z_d)$$ | $$W_{eff} := \frac{I_{eff}}{max_{z.eff}}$$ | $$W_{eff} = 1.612 \cdot 10^5 \, \text{·} mm^3$$ |

| Compare gross section | $$z_{d_i} := \left| z_i - z_{gc.gr} \right|$$ | $$max_{z.gr} := max(z_d)$$ | $$W_{gr} := \frac{I_{y.gr}}{max_{z.gr}}$$ | $$W_{gr} = 1.853 \cdot 10^5 \, \text{·} mm^3$$ |

Heat Affected Zone

Reduced thickness in HAZ
$$h := 2..3 \quad t_h := \rho_{haz} \cdot t_h \quad t_{h+3} := t_h \quad t_9 := \rho_{haz} \cdot t_h \quad t_{15} := \rho_{haz} \cdot t_h$$

Area
$$dA_i := \overrightarrow{\left[t_i \cdot \sqrt{(y_i - y_{i-1})^2 + (z_i - z_{i-1})^2} \right]}$$

| Area of effective cross section | $$A_{ele} := \sum_{i=1}^{rows(y)-1} dA_i$$ | $$A = 5.52 \cdot 10^3 \, \text{·} mm^2$$ |
| | | $$A_{ele} = 5.126 \cdot 10^3 \, \text{·} mm^2$$ |

| First moment of area. Gravity centre | $$S_y := \sum_{i=1}^{rows(y)-1} (z_i + z_{i-1}) \cdot \frac{dA_i}{2}$$ | $$z_{gc.e} := \frac{S_y}{A_{ele}}$$ |
| | | $$z_{gc.e} = -44.228 \, \text{·} mm$$ |

| Second moment of area of effective cross section | $$I_y := \sum_{i=1}^{rows(y)-1} \left[(z_i)^2 + (z_{i-1})^2 + z_i \cdot z_{i-1} \right] \cdot \frac{dA_i}{3}$$ | $$I_{ele} := I_y - A_{ele} \cdot z_{gc.e}^2$$ |
| | | $$I_{ele} = 1.013 \cdot 10^7 \, \text{·} mm^4$$ |

| Section modulus | $$z_{d_i} := \left| z_i - z_{gc.e} \right|$$ | $$max_{z.ele} := max(z_d)$$ | $$W_{ele} := \frac{I_{ele}}{max_{z.ele}}$$ | $$W_{ele} = 1.849 \cdot 10^5 \, \text{·} mm^3$$ |
| | | | | $$W_{el} = 1.853 \cdot 10^5 \, \text{·} mm^3$$ |

Plastic section modulus

Area of effective cross section

$$A_{pl} := \left[\sum_{i=1}^{rows(y)-1} \left[t_i \cdot \sqrt{(y_i - y_{i-1})^2 + (z_i - z_{i-1})^2}\right]\right]$$

$A = 5.52 \cdot 10^3 \circ mm^2$

$A_{pl} = 5.126 \cdot 10^3 \circ mm^2$

Cross section area of upper part

$$A_{up} := \left[\sum_{i=1}^{7} \left[t_i \cdot \sqrt{(y_i - y_{i-1})^2 + (z_i - z_{i-1})^2}\right]\right] + 2 \cdot \left[t_9 \cdot \sqrt{(y_9 - y_8)^2 + (z_9 - z_8)^2}\right]$$

$A_{up} = 2.486 \cdot 10^3 \circ mm^2$

Move node 8 to plastic neutral axis

$$z_{10} := z_9 - \frac{\frac{A}{2} - A_{up}}{t_{11} + t_{13}}$$

$z_9 = -30 \circ mm$

$z_{13} := z_{10}$

$z_{10} = -47.1 \circ mm$

$$y_{10} := y_5 - \frac{z_{10}}{z_{11}} \cdot (y_5 - y_{11})$$

$y_{13} := -y_{10}$

$y_{10} = 96 \circ mm$

Plastic section modulus

$$W_{ple} := \sum_{i=1}^{rows(y)-1} \frac{\left|z_i + z_{i-1}\right|}{2} \cdot \left[t_i \cdot \sqrt{(y_i - y_{i-1})^2 + (z_i - z_{i-1})^2}\right]$$

$W_{ple} = 2.267 \cdot 10^5 \circ mm^3$

$$\frac{W_{ple}}{W_{el}} = 1.224$$

~~Shape factor~~

Shape factor

(5.15)

$$\alpha_{3I} = \frac{W_{ele}}{W_{el}} \cdot \left[1 + \frac{15 - \beta_{Imax}}{15 - 11} \cdot \left(\frac{W_{ple}}{W_{ele}} - 1 \right) \right] \qquad \alpha_{3O} = \frac{W_{ele}}{W_{el}} \cdot \left[1 + \frac{4 - \beta_{Omax}}{4 - 3} \cdot \left(\frac{W_{ple}}{W_{ele}} - 1 \right) \right]$$
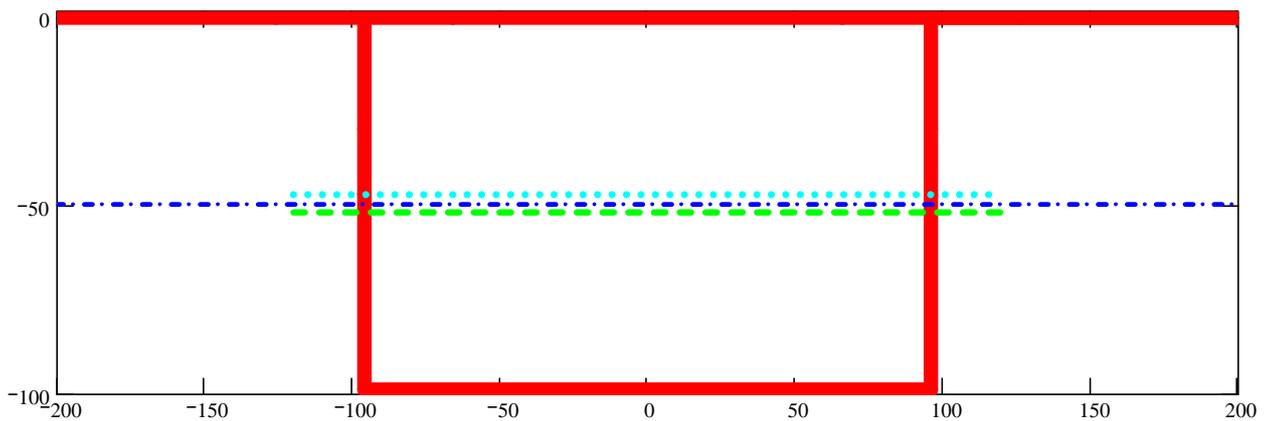
$$\alpha_{3I} = 0.296 \qquad\qquad\qquad \alpha_{3O} = 1.465$$

$$\alpha_{3} = if\left(\alpha_{3I} < \alpha_{3O}, \alpha_{3I}, \alpha_{3O} \right) \qquad\qquad \alpha_{3} = 1.465$$

$$\alpha := if\left(class < 3, \frac{W_{ple}}{W_{el}}, if\left(class < 4, \alpha_{3}, \frac{W_{eff}}{W_{el}} \right) \right) \qquad class = 4 \qquad \alpha = 0.87$$

Elastic neutral axis:
 - first iteration   dashed-dotted line
 - second iteration   dashed line
Plastic neutral axis   dotted line

Bending moment resistance

(5.14)

$$M_{y.Rd} := \alpha \cdot W_{el} \cdot \frac{f_o}{\gamma_{M1}}$$

$$M_{y.Rd} = 29.3 \circ kN \cdot m$$

$W_{el} = 1.853 \cdot 10^5 \circ mm^3$

$W_{ple} = 2.267 \cdot 10^5 \circ mm^3$

Cross section class

$class = 4$

$\alpha = 0.87$

$A_{eff} = 4.424 \cdot 10^3 \circ mm^2$

$I_{eff} = 8.344 \cdot 10^6 \circ mm^4$