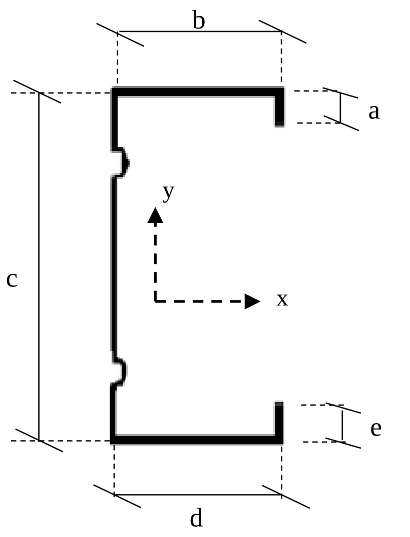
Appendix A: Ambient Temperature Axial Compression Capacity of 92*1.15 mm Peer Stud

A1 Based on Effective Width Method (EWM) – AS/NZS 4600 (SA, 2005)

A1.1 Stud Dimensions and Properties



Measured External Dimensions

A = 7.3 mm, B = 36.1 mm, C = 93.1 mm, D = 33.7 mm and E = 7.1 mm.

Nominal External Dimensions (Peer Stud Manual)

A = 8.1 mm, B = 35.4 mm, C = 92.0 mm, D = 33.5 mm and E = 6.4 mm.

Thickness (BMT) – 1.15 mm

Note: 1. Nominal dimensions are used in the design calculations

2. Stud was assumed to be singly symmetric with B=D= 35.4 mm and A=E= 8.1 mm.

3. Two small stiffeners present in the web elements are neglected in the design calculations.

4. Dimensions A to E are stud external dimensions and a to e are centerline dimensions

Effective length about the major axis of bending L_x = 3,000 mm

Effective length about the minor axis of bending L_y = 300 mm (screw spacing at 300 mm c/c)

Section properties of the Stud (from CUFSM):

Gross area of the section A_g = 196.99 mm^2

Second moment of area about the major axis I_{xx} = 259,329 mm^4

Second moment of area about the minor axis I_{yy} = 27,489 mm^4

Radius of gyration about major axis $r_x = \sqrt{\frac{I_{xx}}{A_g}} = \sqrt{\frac{259{,}329}{196.99}} = 36.28\,\text{mm}$

Radius of gyration about minor axis $r_y = \sqrt{\frac{I_{yy}}{A_g}} = \sqrt{\frac{27{,}489}{196.99}} = 11.81\,\text{mm}$

Mechanical properties of the Stud (Nominal values):

Yield Strength at ambient temperature $f_{y,20}$ = 300 MPa

Elastic modulus at ambient temperature E_{20} = 200 000 MPa

A1.2 Critical stress (f_n) – Cl 3.4 AS/NZS 4600 (SA, 2005)

Plasterboard provides torsional and flexural-torsional buckling restraints to the Peer Studs in gypsum plasterboard lined walls, thus the stud sections are not subjected to torsional or flexural-torsional buckling.

Elastic flexural buckling stress about the major axis f_{ox}

$$f_{ox} = \frac{\pi^2 E}{\left(\frac{l_{ex}}{r_x}\right)^2} = \frac{\pi^2 \times 200{,}000}{\left(\frac{3000}{36.28}\right)^2} = 288.68\,\text{MPa}$$

Elastic flexural buckling stress about the minor axis f_{oy}

$$f_{oy} = \frac{\pi^2 E}{\left(\frac{l_{ey}}{r_y}\right)^2} = \frac{\pi^2 \times 200{,}000}{\left(\frac{300}{11.81}\right)^2} = 3059.05\,\text{MPa}$$

Elastic flexural buckling stress f_{oc} = Lesser of f_{ox} and f_{oy} = 288.68 MPa

Non-dimensional slenderness $\lambda_c = \sqrt{\frac{f_y}{f_{oc}}} = \sqrt{\frac{300}{288.68}} = 1.019 < 1.5$

Critical stress $f_n = \left(0.658^{\lambda_c^2}\right) f_y$ for $\lambda_c \le 1.5$

$$= \left(0.658^{1.019^2}\right) \times 300 = 194.26\,\text{MPa}$$

A1.3 Effective widths of uniformly compressed elements

A1.3.1 Web

Effective width of uniformly compressed stiffened elements - Cl 2.2.1 AS/NZS 4600 (SA, 2005)

Plate elastic buckling stress $f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2 = \left(\frac{4 \times \pi^2 \times 200{,}000}{12(1-0.3^2)}\right)\left(\frac{1.15}{90.85}\right)^2$

= 115.85 MPa

The slenderness ratio $\lambda = \sqrt{\frac{f_n}{f_{cr}}} = \sqrt{\frac{194.26}{115.85}} = 1.295 > 0.673$

Effective width factor $\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} = \frac{\left(1 - \frac{0.22}{1.295}\right)}{1.295} = 0.64$

$c_{eff} = 0.64 \times 90.85 = 58.14\,\text{mm}$

A1.3.2 Flange

Effective widths of uniformly compressed elements with an edge stiffener - Cl 2.4 AS/NZS 4600 (SA, 2005)

Slenderness factor $S = 1.28\sqrt{\frac{E}{f_n}} = 1.28\sqrt{\frac{200{,}000}{194.26}} = 41.07$

$0.328S = 0.328 \times 41.07 = 13.47$

$$\frac{b}{t} = \frac{34.25}{1.15} = 29.78$$

$$\frac{b}{t} > 0.328S$$

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \leq t^4\left[115\frac{(b/t)}{S} + 5\right]$$

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 = 399 \times 1.15^4\left[\frac{(34.25/1.15)}{41.07} - 0.328\right]^3 = 43.72\ \text{mm}^4$$

$$I_a = t^4\left[115\frac{(b/t)}{S} + 5\right] = 1.15^4\left[115\frac{(34.25/1.15)}{41.07} + 5\right] = 154.60\ \text{mm}^4$$

$$I_a = 43.72\ \text{mm}^4$$

$$I_s = \frac{d^3 t \,\text{Sin}^2\Theta}{12} = \frac{7.53^3 \times 1.15 \times \text{Sin}^2 90}{12} = 40.92\,\text{mm}^4 < I_a$$

$$I_s = 40.92\ \text{mm}^4$$

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \geq 1/3$$

$$\left[0.582 - \frac{(34.25/1.15)}{4 \times 41.07}\right] = 0.401$$

$$n = 0.401$$

$$\frac{d_1}{b} = \frac{7.53}{34.25} = 0.22 \qquad \frac{d_1}{b} \leq 0.25$$

Plate buckling coefficient k based on Table 2.4.2 of AS/NZS 4600 (SA, 2005)

$$k = 3.57\left(\frac{I_s}{I_a}\right)^n + 0.43 \leq 4$$

$$k = 3.57\left(\frac{40.92}{43.72}\right)^{0.401} + 0.43 = 3.906 < 4 \qquad k = 3.906$$

Plate elastic buckling stress $f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2 = \left(\frac{3.906 \times \pi^2 \times 200{,}000}{12(1-0.3^2)}\right)\left(\frac{1.15}{34.25}\right)^2$

= 796.00 MPa

The slenderness ratio $\lambda = \sqrt{\frac{f_n}{f_{cr}}} = \sqrt{\frac{194.26}{796.00}} = 0.494 < 0.673$

Effective width factor $\rho = 1$

$b_{eff} = b = 34.25\,\text{mm}$

$b_{eff1} = \frac{b_{eff}}{2}\left(\frac{I_s}{I_a}\right)$

$b_{eff1} = \frac{34.25}{2} \times \left(\frac{40.92}{43.72}\right) = 16.03\,\text{mm}$

$b_{eff2} = b_{eff} - b_{eff1} = 34.25 - 16.03 = 18.22\,\text{mm}$

A1.3.3 Lip

Effective width of uniformly compressed unstiffened elements - Cl 2.3.1 AS/NZS 4600 (SA, 2005)

Plate elastic buckling stress $f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2 = \left(\frac{0.43 \times \pi^2 \times 200{,}000}{12(1-0.3^2)}\right)\left(\frac{1.15}{7.53}\right)^2$

=1812.93 MPa

The slenderness ratio $\lambda = \sqrt{\frac{f_n}{f_{cr}}} = \sqrt{\frac{194.26}{1812.93}} = 0.327 < 0.673$

Effective width factor $\rho = 1$

$a_{eff} = a \times \left(\frac{I_s}{I_a}\right) = 7.53 \times \left(\frac{40.92}{43.72}\right) = 7.05\,\text{mm}$

$a_{eff} = 7.05\,\text{mm}$

A1.4 Nominal member capacity (N_c)

Effective area of 92*1.15 mm Peer Stud in pure compression at ambient temperature A_{eff}

$= \{58.14 + 7.05 + 34.25 + 7.05 + 34.25\} x 1.15 = 161.85\ \text{mm}^2$

Nominal Member Capacity N_c $= A_{eff} x f_n$ = 161.85 x 194.26

= 31.44 kN

A1.5 Nominal section capacity (N_s)

A1.5.1 Web

The slenderness ratio $\lambda = \sqrt{\frac{f_y}{f_{cr}}} = \sqrt{\frac{300}{115.85}} = 1.609 > 0.673$

Effective width factor $\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} = \frac{\left(1 - \frac{0.22}{1.609}\right)}{1.609} = 0.54$

$c_{eff} = 0.54 \times 90.85 = 49.06\,\text{mm}$

A1.5.2 Flange

Slenderness factor $S = 1.28\sqrt{\frac{E}{f_y}} = 1.28\sqrt{\frac{200{,}000}{300.00}} = 33.05$

$0.328S = 0.328 \times 33.05 = 10.84$

$$\frac{b}{t} = \frac{34.25}{1.15} = 29.78$$

$$\frac{b}{t} > 0.328S$$

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 = 399 \times 1.15^4\left[\frac{(34.25/1.15)}{33.05} - 0.328\right]^3 = 131.38\,\text{mm}^4$$

$$I_a = t^4\left[115\frac{(b/t)}{S} + 5\right] = 1.15^4\left[115\frac{(34.25/1.15)}{33.05} + 5\right] = 190.00\ \text{mm}^4$$

$$I_a = 131.38\ \text{mm}^4$$

$$I_s = \frac{d^3 t \operatorname{Sin}^2\Theta}{12} = \frac{7.53^3 \times 1.15 \times \operatorname{Sin}^2 90}{12} = 40.92\,\text{mm}^4 < I_a$$

$$I_s = 40.92\ \text{mm}^4$$

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge 1/3$$

$$\left[0.582 - \frac{(34.25/1.15)}{4 \times 33.05}\right] = 0.357 \qquad n = 0.357$$

$\frac{d_1}{b} = \frac{7.53}{34.25} = 0.22$ $\qquad\qquad$ $\frac{d_1}{b} < 0.25$

Plate buckling coefficient k based on Table 2.4.2 of AS/NZS 4600 (SA, 2005)

$$k = 3.57\left(\frac{I_s}{I_a}\right)^n + 0.43 \le 4$$

$$k = 3.57\left(\frac{40.92}{131.38}\right)^{0.357} + 0.43 = 2.784 < 4 \qquad k = 2.784$$

Plate elastic buckling stress $f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2 = \left(\frac{2.784\times\pi^2\times 200{,}000}{12(1-0.3^2)}\right)\left(\frac{1.15}{34.25}\right)^2$

= 567.35 MPa

The slenderness ratio $\lambda = \sqrt{\frac{f_y}{f_{cr}}} = \sqrt{\frac{300.00}{567.35}} = 0.727 > 0.673$

Effective width factor $\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} = \frac{\left(1 - \frac{0.22}{0.727}\right)}{0.727} = 0.96$

$b_{eff} = 0.96 \times 34.25 = 32.88\,\text{mm}$

$$b_{eff1} = \frac{b_{eff}}{2}\left(\frac{I_s}{I_a}\right)$$

$$b_{eff1} = \frac{32.88}{2} \times \left(\frac{40.92}{131.38}\right) = 5.33\,\text{mm}$$

$$b_{eff2} = b_{eff} - b_{eff1} = 32.88 - 5.33 = 27.55\,\text{mm}$$

<u>A1.5.3 Lip</u>

The slenderness ratio $\lambda = \sqrt{\frac{f_y}{f_{cr}}} = \sqrt{\frac{300}{1812.93}} = 0.41 < 0.673$

Effective width factor $\rho = 1$

$$a_{eff} = a \times \left(\frac{I_s}{I_a}\right) = 7.53 \times \left(\frac{40.92}{131.38}\right) = 2.35\,\text{mm}$$

Effective area of 92*1.15 mm Peer Stud in pure compression at ambient temperature A_{eff}

$= \{49.06 + 2.35 + 32.88 + 2.35 + 32.88\}\text{x}1.15 = 137.45\ \text{mm}^2$

Nominal Section Capacity N_s $= A_{eff}\,\text{x}\,f_y$ = 137.45 x 300

= 41.24 kN

A1.6: Nominal distortional buckling capacity (N_d)

$f_{od} = 0.889 \times 300 = 266.70$ MPa (from CUFSM distortional buckling load factor = 0.889 – Figure 5(a))

$$\frac{f_y}{2} = \frac{300}{2} = 150 \text{ MPa}$$

$$f_{od} > \frac{f_y}{2}$$

$$f_n = f_y \left\{ 1 - \frac{f_y}{4 f_{od}} \right\} = 300 \left\{ 1 - \frac{300}{4 \times 266.70} \right\} = 215.64 \text{ MPa}$$

Nominal Distortional Buckling Capacity N_d = A_g x f_n

= 196.99 x 215.64

= 42.48 kN

Ultimate Capacity of 92*1.15 mm Peer Stud at Ambient Temperature = 31.44 kN

(Local + flexural buckling modes)

A2 Based on Direct Strength Method (DSM) – AS/NZS 4600 (SA, 2005)

A2.1 Flexural buckling capacity of the stud (N_{ce})

Elastic flexural buckling load $N_{oc} = A_g f_{oc}$

$$= 196.99 \times 288.68 = 56.87\,\text{kN}$$

Nominal yield load $N_y = A_g f_y$

$$= 196.99 \times 300 = 59.10\ \text{kN}$$

$$\lambda_c = \sqrt{\frac{N_y}{N_{oc}}}$$

$$= \sqrt{\frac{59.10}{56.87}} = 1.019 < 1.5$$

Flexural Buckling Capacity $N_{ce} = (0.658^{\lambda_c^2})N_y$

$$= (0.658^{1.019^2}) \times 59.10 = 38.27\ \text{kN}$$

A2.2 Local buckling capacity of the stud

Local buckling load factor =0.61 (see attached CUFSM signature curve for 92*1.15 mm Peer Stud – Figure 5(a))

Critical local buckling load $N_{ol} = A_g \times (\text{Local buckling load factor}) \times f_y$

= 196.99 x (0.61 x 300) = 36.05 kN

$$\lambda_l = \sqrt{\frac{N_{ce}}{N_{ol}}}$$

$$= \sqrt{\frac{38.27}{36.05}} = 1.030 > 0.776$$

Local buckling capacity of the stud $N_{cl} = \left(1 - 0.15\left(\frac{N_{ol}}{N_{ce}}\right)^{0.4}\right)\left(\frac{N_{ol}}{N_{ce}}\right)^{0.4} N_{ce}$

$$= \left(1 - 0.15\left(\frac{36.05}{38.27}\right)^{0.4}\right)\left(\frac{36.05}{38.27}\right)^{0.4} \times 38.27 = 31.89\ \text{kN}$$

If flexural, torsional and flexural-torsional buckling modes are restrained local buckling capacity of the stud is:

$$\lambda_l = \sqrt{\frac{N_y}{N_{ol}}}$$

$$= \sqrt{\frac{59.10}{36.05}} = 1.28 > 0.776$$

Local buckling capacity of the stud $N_{cl} = \left(1 - 0.15\left(\frac{N_{ol}}{N_y}\right)^{0.4}\right)\left(\frac{N_{ol}}{N_y}\right)^{0.4} N_y$

$$= \left(1 - 0.15\left(\frac{36.05}{59.10}\right)^{0.4}\right)\left(\frac{36.05}{59.10}\right)^{0.4} \times 59.10 = 42.53 \text{ kN}$$

<u>A2.3 Distortional buckling capacity of the stud</u>

Distortional buckling load factor = 0.889 (from CUFSM signature curve for 92*1.15 mm Peer Stud – Figure 5(a))

Critical distortional buckling load N_{od} = A_g x (load factor x f_y)

= 196.99 x (0.889 x 300)

= 52.54 kN

$$\lambda_d = \sqrt{\frac{N_y}{N_{od}}}$$

$$= \sqrt{\frac{59.10}{52.54}} = 1.061 > 0.561$$

Distortional buckling capacity of the stud $N_{cd} = \left(1 - 0.25\left(\frac{N_{od}}{N_y}\right)^{0.6}\right)\left(\frac{N_{od}}{N_y}\right)^{0.6} N_y$

$$= \left(1 - 0.25\left(\frac{52.54}{59.10}\right)^{0.6}\right)\left(\frac{52.54}{59.10}\right)^{0.6} \times 59.10 = 42.24 \text{ kN}$$

Ultimate Capacity of 92*1.15 mm Peer Stud at Ambient Temperature = 31.89 kN
(Local + flexural buckling modes)