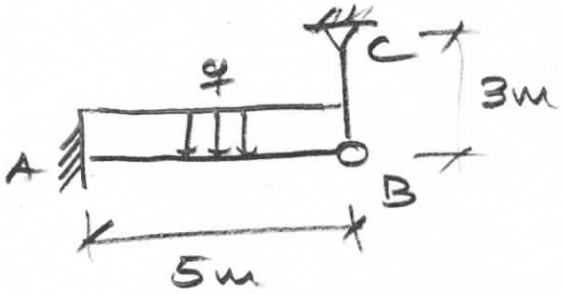
AM16 - B1 - 1000



- EDIFICAÇÃO COMERCIAL;

P.P. EST. METÁLICA: $q_1 = 7\ kN/m$
OCUPAÇÃO : $q_2 = 15\ kN/m$
VENTO : $q_3 = -12\ kN/m$

DETERMINAR O MÁXIMO E O MÍNIMO ESFORÇO AXIAL INCIDENTES NA BARRA $\overline{BC}$.

$\gamma_1 = 1,25 \quad \gamma_2 = 1,50 \quad \gamma_3 = 1,40 \quad \psi_{02} = 0,7 \quad \psi_{03} = 0,6$

- COMB1 (OCUPAÇÃO)

$q_{sd1} = 1,25 \times 7\ kN/m + 1,50 \times 15\ kN/m = 31,25\ kN/m$

- COMB2 (VENTO)

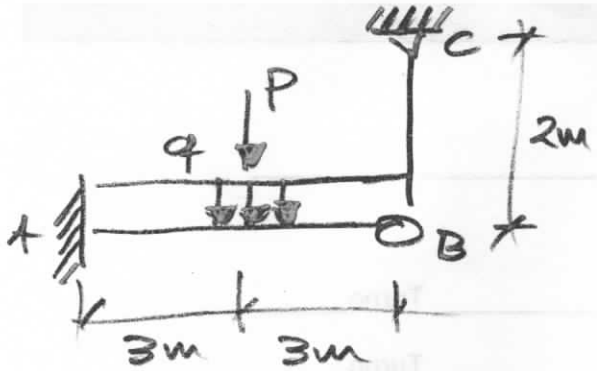
$q_{sd2} = 1,00 \times 7\ kN/m + 1,40 \times (-12\ kN/m) = -9,8\ kN/m$

REAÇÃO $V_{BC} = 3qL/8$ (TRAÇÃO p/ q POSITIVO)

$N_{BC1} = 3/8 \times 31,25\ kN/m \times 5m = 58,59\ kN$ (TRAÇÃO)

$N_{BC2} = 3/8 \times (-9,8)\ kN/m \times 5m = -18,38\ kN$ (COMPRESSÃO)

AM16 - B1 - 0001 → EDIFICAÇÃO COMERCIAL



P.P. EST. METÁLICA : $q_1 = 8\ kN/m$

OCUPAÇÃO : $q_2 = 12\ kN/m$

VENTO : $q_3 = -10\ kN/m$

EQUIP. MÓVEL : $P_1 = 40\ kN$

$\gamma_{q1} = 1,25 \quad \gamma_{q2} = 1,50 \quad \psi_{0q2} = 0,7 \quad \gamma_{q3} = 1,40 \quad \psi_{0q3} = 0,6$

$\gamma_{P1} = 1,50 \quad \psi_{0P1} = 0,7$

COMB1 (OCUP.) $S_{d1} = 1,25 \times 8\ kN/m + 1,5 \times 12\ kN/m + 1,5 \times 40\ kN \times 0,7$

$S_{d1} = 28\ kN/m + 42\ kN$

COMB2 (VENTO) $S_{d2} = 1,00 \times 8\ kN/m - 1,4 \times 10\ kN/m$

$S_{d2} = -6\ kN/m$

COMB3 (EQUIP) $S_{d3} = 1,25 \times 8\ kN/m + 1,5 \times 40\ kN + 1,5 \times 12\ kN/m \times 0,7$

$S_{d3} = 22,6\ kN/m + 60\ kN$

ESF. AXIAL $\overline{BC}$: $3q/8 + 5P/16$

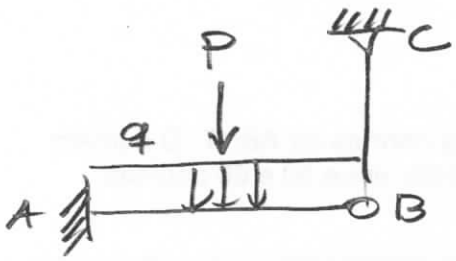
$N_{sd1} = \frac{3}{8} \times 28\ kN/m \times 6m + \frac{5}{16} \times 42\ kN = 76,13\ kN$ (TRAÇÃO)

$N_{sd2} = \frac{3}{8} \times (-6\ kN/m) \times 6m = -13,5\ kN$ (COMP.)

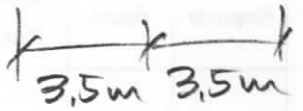
$N_{sd3} = \frac{3}{8} \times 22,6\ kN/m \times 6m + \frac{5}{16} \times 60\ kN = 69,6\ kN$ (TRAÇÃO)

RESPOSTA: $[-13,5\ kN ; +76,13\ kN]$

AM16 - B1 - 1002 EDIFICAÇÃO COMERCIAL



- PP. ESTRUT. METÁLICA : $q_1 = 10\,kN/m$
- PP. ESTRUT. PRÉ MOLD: $P_1 = 40\,kN$
- OCUPAÇÃO : $q_2 = 15\,kN/m$
- VENTO : $q_3 = -12\,kN/m$



DETERMINAR O MÁXIMO E O MÍNIMO ESFORÇO AXIAL QUE PODEM INCIDIR NA BARRA BC;

$\gamma_{q1} = 1,25 \quad \gamma_{P1} = 1,30 \quad \gamma_{q2} = 1,50 \quad \gamma_{q3} = 1,40$

$\psi_{0q2} = 0,7 \quad \psi_{0q3} = 0,6$

COMB1 (OCUPAÇÃO): $Sd_1 = 1,25 \times 10\,kN/m + 1,30 \times 40\,kN + 1,50 \times 15\,kN/m$

$Sd_1 = 35\,kN/m + 52\,kN$

COMB2 (VENTO): $Sd_2 = 1,00 \times 10\,kN/m + 1,00 \times 40\,kN + 1,40 \times -12\,kN/m$

$Sd_2 = -6,8\,kN/m + 40\,kN$

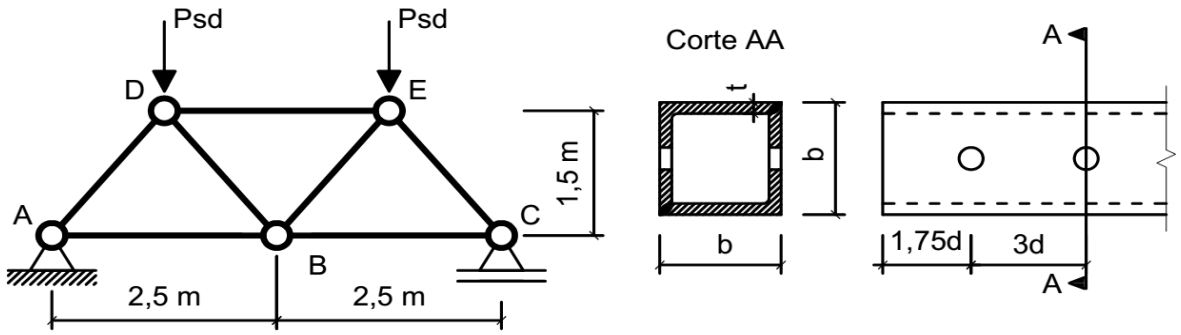
$$N_{Sd_{BC}} = \frac{3}{8} qL + \frac{5}{16} P$$

$$N_{Sd_1} = \frac{3}{8} \times 35\,kN/m \times 7m + \frac{5}{16} \times 52\,kN = 108,1\,kN \text{ (TRAÇÃO)}$$

$$N_{Sd_2} = \frac{3}{8} \times -6,8\,kN/m \times 7m + \frac{5}{16} \times 40\,kN = -5,35\,kN \text{ (COMP.)}$$

AM16-B1-2000

A treliça abaixo será construída com **perfis cantoneiras de abas iguais** soldados conforme o corte AA.
Aço **MR-250**, **b = 50,8 mm**, **t = 4,76 mm**, diâmetro dos parafusos **d = 19 mm**, coeficiente **Ct = 1,0** e **Q = 1,0.**

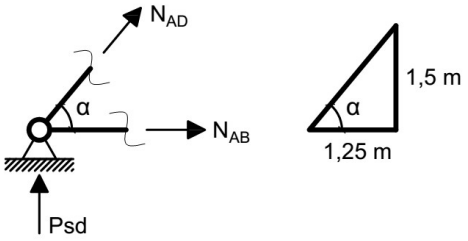


Determinar **qual o máximo valor de carga de cálculo Psd** que pode ser aplicada de modo que as barras AB e AD atendam as verificações de solicitações axiais pertinentes.

* OBS: A carga Psd não inverte sei sentido.

Resolução :

Equilíbrio do Ponto A:



$$h = \sqrt{1{,}5^2 + 1{,}25^2} = 1{,}953$$

$$\cos\alpha = \frac{1{,}25}{h} = 0{,}6400 \qquad sen\alpha = \frac{1{,}50}{h} = 0{,}7680$$

$$\sum Fv = 0 \ (+ \ para \ cima)$$

$$Psd = - \ N_{AD} \ . \ sen\alpha \ \ (barra \ AD \ comprimida)$$

$$\sum Fh = 0 \ (+ \ para \ direita) \quad N_{AB} = - \ N_{AD} \ . \ \cos\alpha = -\left(\frac{-Psd}{sen\alpha}\right) \ . \ \cos\alpha$$

$$Psd = N_{AB} \ . \ \frac{sen\alpha}{\cos\alpha} \ \ (barra \ AB \ tracionada)$$

Dados Geométricos:

$$A_g = b^2 - (b - 2t)^2 = (5{,}08\,cm)^2 - (5{,}08\,cm - 2 \ . \ 0{,}476\,cm)^2 = 8{,}766 \ \ cm^2$$

$$d_{pad} = 1{,}9\,cm + 0{,}35\,cm = 2{,}25 \ \ cm$$

$$A_n = A_e \ (dado \ que \ Ct = 1{,}0) \ \rightarrow \ A_e = 8{,}766\,cm^2 - 2 \times 2{,}25\,cm \times 0{,}476\,cm = 6{,}624 \ \ cm^2$$

$$A_{gv} = 2 \times (1{,}75\,d + 3\,d) \times t = 2 \times 4{,}75 \times 1{,}9\,cm \times 0{,}476\,cm = 8{,}592 \ \ cm^2$$

$$A_{nv} = A_{gv} - 3 \times d_{pad} \times t = 8{,}592\,cm^2 - 3 \times 2{,}25\,cm \times 0{,}476\,cm = 5{,}379 \ \ cm^2$$

$$A_{nt} = \frac{A_e}{2} = \frac{6{,}624\,cm^2}{2} = 3{,}312 \ \ cm^2$$

$$I = \frac{b \times b^3}{12} - \frac{(b-2t) \times (b-2t)^3}{12} = \frac{5{,}08^4 - (5{,}08 - 2 \times 0{,}476)^4}{12} = 31{,}30 \ \ cm^4$$

$$r = \sqrt{\frac{I}{A_g}} = \sqrt{\frac{31{,}30\,cm^4}{8{,}766\,cm^2}} = 1{,}890 \ \ cm$$

Verificações da Peça Tracionada AB:

ESB: $N_{tRd} = \dfrac{A_g \times fy}{\gamma_{a1}} = \dfrac{8{,}766\,cm^2 \times 25\,kN/cm^2}{1{,}1} = 199{,}2 \ \ kN$

RSL: $N_{tRd} = \dfrac{A_e \times fu}{\gamma_{a2}} = \dfrac{6{,}624\,cm^2 \times 40\,kN/cm^2}{1{,}35} = 196{,}3 \ \ kN$

CIS:

$$R_{td1} = \frac{1}{1{,}35}\left(0{,}60 \times A_{nv} \times fu + c_{ts} \times A_{nt} \times fu\right) = \frac{1}{1{,}35}\left(0{,}60 \times 5{,}379\,cm^2 \times 40\,kN/cm^2 + 1{,}0 \times 3{,}312\,cm^2 \times 40\,kN/cm2\right) = 193{,}8\,kN$$

$$R_{td2} = \frac{1}{1{,}35}\left(0{,}60 \times A_{gv} \times fy + c_{ts} \times A_{nt} \times fu\right) = \frac{1}{1{,}35}\left(0{,}60 \times 8{,}592\,cm^2 \times 25\,kN/cm^2 + 1{,}0 \times 3{,}312\,cm^2 \times 40\,kN/cm2\right) = 193{,}6\,kN$$

N_{AB}máx. trac = + 193,6 kN

Verificação da Peça Comprimida AD:

$$\lambda = \frac{K \times L_{AD}}{r} = \frac{1,0 \times 195,3\,cm}{1,890} = 103,3$$

$$\lambda_0 = \lambda \times \sqrt{\frac{Q \times fy}{\Pi^2 \times E}} = 103,3 \times \sqrt{\frac{1 \times 25\,kN/cm^2}{\Pi^2 \times 20000\,kN/cm^2}} = 1,163$$

$$Para\ \lambda_0 \leq 1,5 \rightarrow \chi = 0,658^{\lambda_0^2} = 0,658^{1,163^2} = 0,5677$$

$$N_{cRd} = 0,5677 \times 199,2\,kN = 113,1\,kN$$

N_{AD}máx. comp = -113,1 kN

Substituíndo os esforços nas relações com a carga Psd:

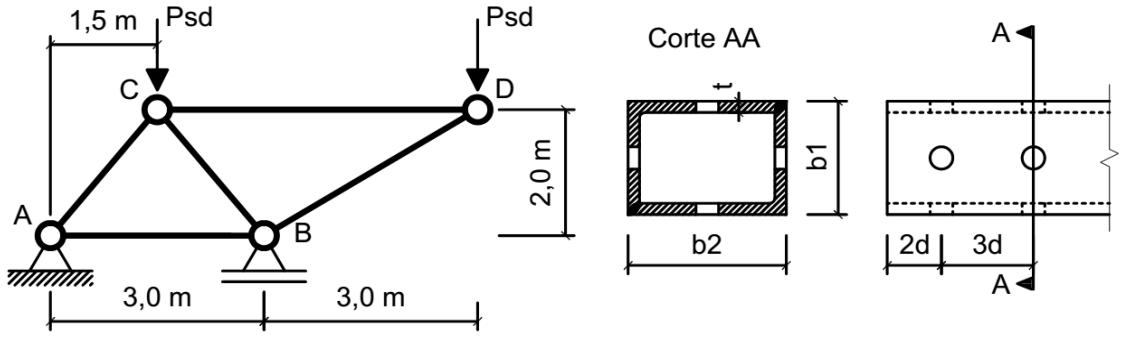
$$Psd = -\ N_{AD}\ .\ sen\alpha = 113,1\,kN \times 0,7680 = 86,86\,kN$$

$$Psd = N_{AB}\ .\ \frac{sen\alpha}{\cos\alpha} = 193,6\,kN \times \frac{0,7680}{0,6400} = 232,3\,kN$$

Máxima carga Psd possível de ser aplicada = 86,86 kN

AM16-B1-2001

A treliça abaixo será construída com **perfis cantoneiras de abas desiguais** soldados conforme o corte AA.
Aço **MR-250**, **b1 = 50,8 mm**, **b2 = 76,2 mm**, **t = 4,76 mm**, diâmetro dos parafusos **d = 19 mm**, coeficiente **Ct = 1,0** e **Q = 1,0.**

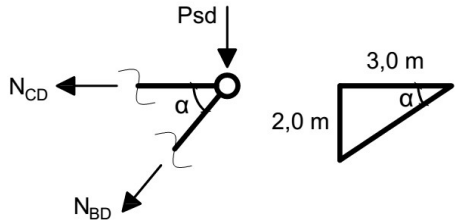


Determinar **qual o máximo valor de carga de cálculo Psd** que pode ser aplicada de modo que as barras CD e BD atendam as verificações de solicitações axiais pertinentes.

* OBS: A carga Psd não inverte sei sentido.

Resolução :

Equilíbrio do Ponto A:



$$h = \sqrt{3^2+3^2} = \sqrt{13}$$

$$\cos\alpha = \frac{3}{\sqrt{13}} = 0{,}8321 \qquad sen\alpha = \frac{2}{\sqrt{13}} = 0{,}5547$$

$$\sum Fv = 0 \ (+ \ para \ \ baixo)$$

$$Psd = - N_{BD} \times sen\alpha \ \ (barra \ \ BD \ \ comprimida)$$

$$\sum Fh = 0 \ (+ \ para \ \ esquerda) \quad N_{CD} = - N_{BD} \ . \ \cos\alpha = -\left(\frac{-Psd}{sen\alpha}\right) \ . \ \cos\alpha$$

$$Psd = N_{CD} \ . \ \frac{sen\alpha}{\cos\alpha} \ \ (barra \ \ CD \ \ tracionada)$$

Dados Geométricos:

$$A_g = b1 \times b2 - (b1-2t) \times (b1-2t) = (5{,}08\,cm \times 7{,}62\,cm) - (5{,}08\,cm - 2 \times 0{,}476\,cm) \times (7{,}62\,cm - 2 \times 0{,}476\,cm) = 11{,}18 \ \ cm^2$$

$$d_{pad} = 1{,}9\,cm + 0{,}35\,cm = 2{,}25 \ \ cm$$

$$A_n = A_e \ (dado \ \ que \ \ Ct = 1{,}0) \ \rightarrow \ \ A_e = 11{,}18\,cm^2 - 4 \times 2{,}25\,cm \times 0{,}476\,cm = 6{,}896 \ \ cm^2$$

$$A_{gv} = 2 \times (2d + 3d) \times t = 4 \times 5 \times 1{,}9\,cm \times 0{,}476\,cm = 18{,}09 \ \ cm^2$$

$$A_{nv} = A_{gv} - 6 \times d_{pad} \times t = 18{,}09\,cm^2 - 6 \times 2{,}25\,cm \times 0{,}476\,cm = 11{,}66 \ \ cm^2$$

$$A_{nt} = \frac{A_e}{4} = \frac{6{,}896\,cm^2}{4} = 1{,}724 \ \ cm^2$$

$$I_H = \frac{b2 \times b1^3}{12} - \frac{(b2-2t) \times (b1-2t)^3}{12} = \frac{7{,}62 \times 5{,}08^3}{12} - \frac{(7{,}62 - 2 \times 0{,}476) \times (5{,}08 - 2 \times 0{,}476)^3}{12} = 44{,}16\,cm^4$$

$$r = \sqrt{\frac{I}{A_g}} = \sqrt{\frac{44{,}16\,cm^4}{11{,}18\,cm^2}} = 1{,}987 \ \ cm$$

Verificações da Peça Tracionada CD:

ESB: $N_{tRd} = \frac{A_g \times fy}{\gamma_{a1}} = \frac{11{,}18\,cm^2 \times 25\,kN/cm^2}{1{,}1} = 254{,}1 \ \ kN$

RSL: $N_{tRd} = \frac{A_e \times fu}{\gamma_{a2}} = \frac{6{,}896\,cm^2 \times 40\,kN/cm^2}{1{,}35} = 204{,}3 \ \ kN$

CIS:

$$R_{td1} = \frac{1}{1{,}35}\left(0{,}60 \times A_{nv} \times fu + c_{ts} \times A_{nt} \times fu\right) = \frac{1}{1{,}35}\left(0{,}60 \times 11{,}66\,cm^2 \times 40 kN/cm^2 + 1{,}0 \times 1{,}724\,cm^2 \times 40\,kN/cm\,2\right) = 258{,}4 kN$$

$$R_{td2} = \frac{1}{1{,}35}\left(0{,}60 \times A_{gv} \times fy + c_{ts} \times A_{nt} \times fu\right) = \frac{1}{1{,}35}\left(0{,}60 \times 18{,}09\,cm^2 \times 25\,kN/cm^2 + 1{,}0 \times 1{,}724\,cm^2 \times 40\,kN/cm\,2\right) = 252{,}1 kN$$

N_{AB}máx. trac = + 204,3 kN

Verificação da Peça Comprimida BD:

$$\lambda_{BD} = \frac{K_{BD} \times L_{BD}}{r} = \frac{1,0 \times 100\sqrt{13}\,cm}{1,987} = 181,5 < 200 \quad OK!\ para\ compressão$$

$$\lambda_{CD} = \frac{K_{CD} \times L_{CD}}{r} = \frac{1,0 \times 450\,cm}{1,987} = 226,5 < 200 \quad \tilde{N}\,OK!\ para\ compressão\ mas\ OK\ para\ tração\ (<300)$$

BD

$$\lambda_{c} = \lambda_{BD} \times \sqrt{\frac{Q \times fy}{\Pi^2 \times E}} = 181,5 \times \sqrt{\frac{1 \times 25\,kN/cm^2}{\Pi^2 \times 20000\,kN/cm^2}} = 2,043$$

$$Para\ \lambda_0 > 1,5 \rightarrow \chi = \frac{0,877}{\lambda_0^2} = \frac{0,877}{2,043^2} = 0,2101$$

$$N_{cRd} = 0,2101 \times 254,1\,kN = 53,38\,kN$$

N_{AD}máx. Comp = -53,38 kN

Substituíndo os esforços nas relações com a carga Psd:

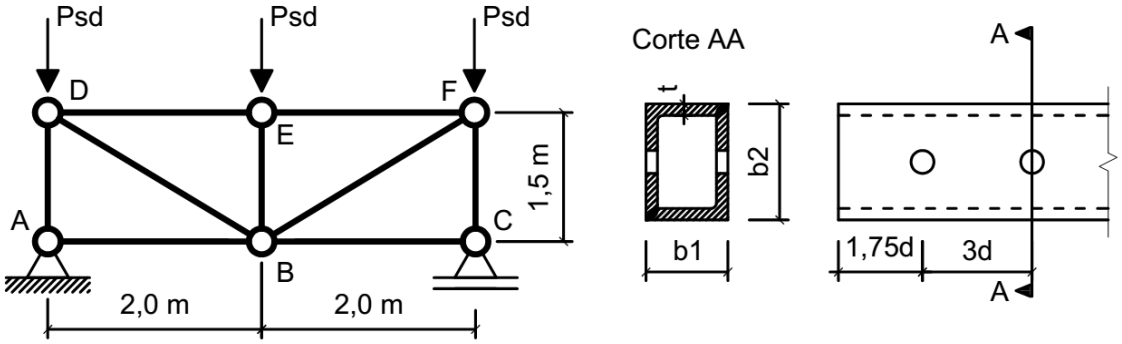
$$Psd = -\ N_{BD}\ .\ sen\,\alpha = 53,38\,kN \times 0,5547 = 29,61\,kN$$

$$Psd = N_{CD}\ .\ \frac{sen\,\alpha}{\cos\alpha} = 204,3\,kN \times \frac{0,5547}{0,8321} = 136,2\,kN$$

Máxima carga Psd possível de ser aplicada = 29,61 kN

AM16-B1-2002

A treliça abaixo será construída com **perfis cantoneiras de abas desiguais** soldados conforme o corte AA.
Aço **MR-250**, **b1 = 64 mm**, **b2 = 89 mm**, **t = 6,3 mm**, diâmetro dos parafusos **d = 16 mm**, coeficiente **Ct = 1,0** e **Q = 1,0.**

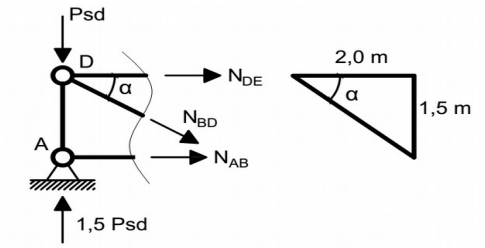


Determinar **qual o máximo valor de carga de cálculo Psd** que pode ser aplicado de modo que as barras DE e BD atendam as verificações de solicitações axiais pertinentes.

* OBS: A carga Psd não inverte sei sentido.

Resolução :

Esforços NDE e NBD em função da Carga Psd:



$$L_{BD} = \sqrt{2^2+1,5^2} = 2,5$$

$$\cos\alpha = \frac{2}{2,5} = 0,8000 \qquad sen\,\alpha = \frac{1,5}{2,5} = 0,6000$$

$$\sum Fv = 0 \quad (+ \ para \ \ cima)$$

$$-Psd + 1,5\,Psd - N_{BD} \times sen\,\alpha = 0$$

$$\frac{1}{2}Psd = N_{BD} \times sen\,\alpha \ \rightarrow \ Psd = 1,2 \times N_{BD} \quad (barra \ \ BD \ \ tracionada)$$

$$\sum M_A = 0 \quad (+ \ hor\acute{a}rio)$$

$$N_{DE} \times 1,5 + N_{BD} \times \cos\alpha \times 1,5 = 0$$

$$N_{DE} \times 1,5 + \frac{Psd}{2 \times sen\,\alpha} \times \cos\alpha \times 1,5 = 0$$

$$Psd = -2 \times N_{DE} \times \frac{sen\,\alpha}{\cos\alpha} \ \rightarrow \ Psd = -1,5 \times N_{DE} \quad (barra \ \ DE \ \ comprimida)$$

Dados Geométricos:

$$A_g = b1 \times b2 - (b1-2t) \times (b1-2t) = (6,4\,cm \times 8,9\,cm) - (6,4\,cm - 2 \times 0,63\,cm) \times (8,9\,cm - 2 \times 0,63\,cm) = 17,69 \ \ cm^2$$

$$d_{pad} = 1,6\,cm + 0,35\,cm = 1,95 \ \ cm$$

$$A_n = A_e \ (dado \ \ que \ \ Ct = 1,0) \ \rightarrow \ A_e = 17,69\,cm^2 - 2 \times 1,95\,cm \times 0,63\,cm = 15,23 \ \ cm^2$$

$$A_{gv} = 2 \times (1,75\,d + 3\,d) \times t = 2 \times 4,75 \times 1,6\,cm \times 0,63\,cm = 9,576 \ \ cm^2$$

$$A_{nv} = A_{gv} - 3 \times d_{pad} \times t = 9,576\,cm^2 - 3 \times 1,95\,cm \times 0,63\,cm = 5,891 \ \ cm^2$$

$$A_{nt} = \frac{A_e}{2} = \frac{15,23\,cm^2}{2} = 7,615 \ \ cm^2$$

$$I_V = \frac{b2 \times b1^3}{12} - \frac{(b2-2t) \times (b1-2t)^3}{12} = \frac{8,9 \times 6,4^3}{12} - \frac{(8,9-2 \times 0,63) \times (6,4-2 \times 0,63)^3}{12} = 108,0\,cm^4$$

$$r = \sqrt{\frac{I}{A_g}} = \sqrt{\frac{108,0\,cm^4}{17,69\,cm^2}} = 2,471 \ \ cm$$

Verificações da Peça Tracionada BD:

ESB: $N_{tRd} = \dfrac{A_g \times fy}{\gamma_{a1}} = \dfrac{17,69\,cm^2 \times 25\,kN/cm^2}{1,1} = 402,0 \ \ kN$

RSL: $N_{tRd} = \dfrac{A_e \times fu}{\gamma_{a2}} = \dfrac{15,23\,cm^2 \times 40\,kN/cm^2}{1,35} = 451,3 \ \ kN$

CIS:

$$R_{td1} = \frac{1}{1,35}\left(0,60\times A_{nv}\times fu + c_{ts}\times A_{nt}\times fu\right) = \frac{1}{1,35}\left(0,60\times 5,891\,cm^2\times 40\,kN/cm^2 + 1,0\times 7,615\,cm^2\times 40\,kN/cm^2\right) = 330,4\,kN$$

$$R_{td2} = \frac{1}{1,35}\left(0,60\times A_{gv}\times fy + c_{ts}\times A_{nt}\times fu\right) = \frac{1}{1,35}\left(0,60\times 9,576\,cm^2\times 25\,kN/cm^2 + 1,0\times 7,615\,cm^2\times 40\,kN/cm2\right) = 332,0\,kN$$

N_{AB}máx. trac = + 330,4 kN

Verificação da Peça Comprimida DE:

$$\lambda_{DE} = \frac{K_{DE}\times L_{DE}}{r} = \frac{1,0\times 200\,cm}{2,471\,cm} = 80,94 < 200 \quad OK!\ para\ compressão$$

$$\lambda_{0\,DE} = \lambda_{DE}\times\sqrt{\frac{Q\times fy}{\pi^2\times E}} = 80,94\times\sqrt{\frac{1\times 25\,kN/cm^2}{\pi^2\times 20000\,kN/cm^2}} = 0,9109$$

$$Para\ \lambda_0 \le 1,5 \rightarrow \chi = 0,658^{\lambda_0^2} = 0,658^{0,9109^2} = 0,7066$$

$$N_{cRd} = 0,7066\times 402,0\,kN = 284,1\,kN$$

N_{AD}máx. Comp = -284,1 kN

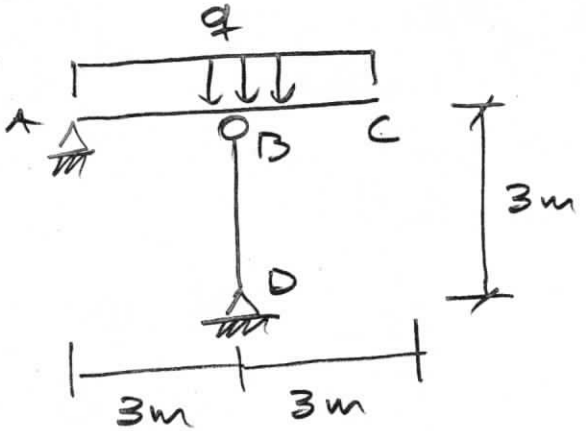
Substituíndo os esforços nas relações com a carga Psd:

$$Psd = 1,2\times N_{BD} = 1,2\times 330,4\,kN = 396,5\,kN$$

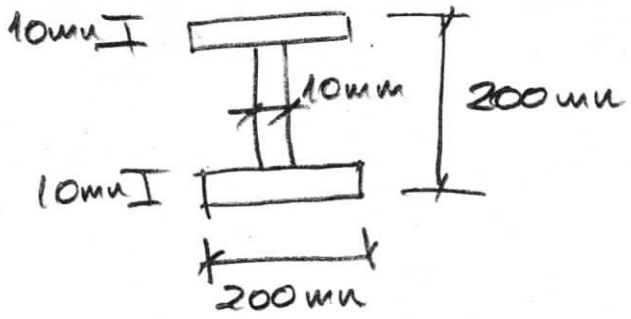
$$Psd = -2,25\times N_{DE} = -1,5\times -284,1\,kN = 426,2\,kN$$

Máxima carga Psd possível de ser aplicada = 396,5 kN

AM16-B1-3000



PERFIL SOLDADO BARRA BD



• AÇO MR 250

DETERMINAR O MÁXIMO VALOR DA CARGA DISTRIBUÍDA "q" P/ QUE A BARRA BD AINDA ATENDA À SOLICITAÇÃO DE COMPRESSÃO.

$\Sigma M_A = 0 \curvearrowleft (+) \quad V_D \times 3 - q \times 6^2/2 = 0 \quad V_B = 1/3\, q 6^2/2$

$N_{csd_{BD}} = 6q$

$I_y = \frac{18 \times 1^3}{12} + 2\left[\frac{1 \times 20^3}{12}\right] = 1334{,}8\ cm^4$

$A_g = 1 \times 18 + 2[1 \times 20] = 58\ cm^2$

$r_y = \sqrt{\frac{1334{,}8}{58}} = 4{,}797\ cm$

$\lambda_y = K_y L_y / r_y = 1{,}0 \times 300cm / 4{,}797cm = 62{,}54 < 200$ ok!

$Q = ?$ Fator de Flambagem Local

ELEMENTO AA:

$b/t = 180mm/10mm = 18$

$b/t_{lim} = 1{,}49\sqrt{E/f_y} = 42{,}13$

$\Big\} \ Q_a = 1{,}0$

ELEMENTO AL:

$b/t = \frac{200\,mm \times 0,5}{10\,mm} = 10$ $\quad k_c = \frac{4}{\sqrt{18}} = 0,9428 \rightarrow 0,76$

$b/t_{lim} = 0,64\sqrt{\frac{20000}{25/0,76}} = 15,78$

$Q_s = 1,0$

$Q = Q_a \times Q_s = 1 \times 1 = 1$

$\chi = ?$ Fator de Flambagem Global

$\lambda_{oy} = \lambda_y \sqrt{\frac{Q \cdot f_y}{\pi^2 E}} = 62,54\sqrt{\frac{1 \times 25}{\pi^2 \times 20000}} = 0,7038$

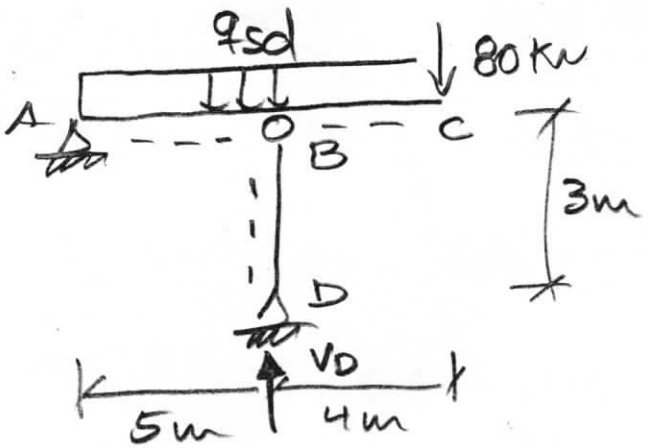
$\chi = 0,658^{0,7038^2} = 0,8106$

$N_{crd} = \chi \cdot Q \cdot A_g \cdot f_y / \gamma_{a1} = 0,8106 \times 1 \times 58\,cm^2 \times 25\,kN/cm^2 / 1,1$

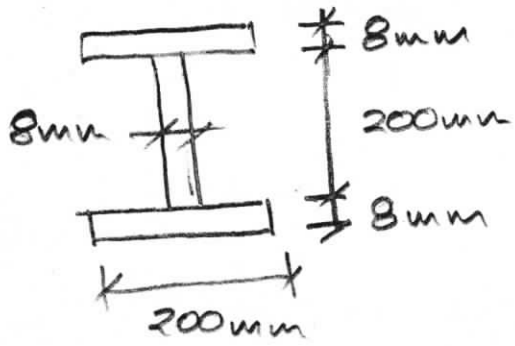
$N_{crd} = 1069\,kN$

$q = \frac{N_{crd}}{6} = \frac{1069\,kN}{6\,m} = \boxed{178,2\,kN/m}$

AM16-B1-3001



PERFIL SOLDADO DA COLUNA BD



DETERMINAR O MÁXIMO qsd [kN/m] POSSÍVEL DE SER APLICADO DE MODO QUE A COLUNA BD ATENDA AS VERIFICAÇÕES DE COMPRESSÃO CENTRADA.

AÇO MR250 & VINCULAÇÃO IGUAL P/ EIXO X E EIXO Y.

$$\sum M_A = 0 \curvearrowleft (+) \quad V_D \times 5m - 80kN \times 9m - qsd \times (9m)^2/2 = 0$$

$$V_D = \frac{1}{5m}\left(720 kNm + 40{,}5\, qsd\, m^2\right)$$

$$V_D = 144kN + 8{,}1\, qsd\, m \qquad qsd = \frac{V_D - 144}{8{,}1}$$

$$I_y = \frac{20 \times 9{,}8^3}{12} + 2\left[\frac{9{,}8 \times 20^3}{12}\right] = 1067{,}5\, cm^4$$

$$A_g = 20 \times 0{,}8 + 2 \times 0{,}8 \times 20 = 48 cm^2$$

$$r_y = \sqrt{\frac{1067{,}5}{48}} = 4{,}716 cm$$

$$\lambda_y = k_y \cdot L_y / r_y = 1 \times 300 cm / 4{,}716 cm = 63{,}61 < 200 \quad \text{ok!}$$

Q=? FATOR DE FL. LOCAL

ELEMENTO AA: $b/t = 200\,mm / 8\,mm = 25$

$b/t_{lim} = 1{,}49\sqrt{E/f_y} = 42{,}14$

$\Rightarrow Q_a = 1$

ELEMENTO AL: $b/t = 200\,mm \times 0{,}5 / 8\,mm = 12{,}5$

$k_c = 4/\sqrt{25} = 0{,}8 \rightsquigarrow 0{,}76$ $\quad b/t_{lim} = 0{,}64\sqrt{\frac{20000 \times 0{,}76}{25}} = 15{,}78$

$Q_s = 1$ $\qquad Q = Q_a \times Q_s = 1 \times 1 = 1$

χ=? FATOR DE FL. GLOBAL

$\lambda_{oy} = \lambda_y\sqrt{\frac{Q \cdot f_y}{\pi^2 E}} = 63{,}61\sqrt{\frac{1 \times 25}{\pi^2 \times 20000}} = 0{,}7159$

$\chi = 0{,}658^{0{,}7159^2} = 0{,}8069$

$N_{crd} = \chi \cdot Q \cdot A_g \cdot f_y / \gamma_{a1} = 0{,}8069 \times 1 \times 48\,cm^2 \times 25\,kN/cm^2 / 1{,}1$

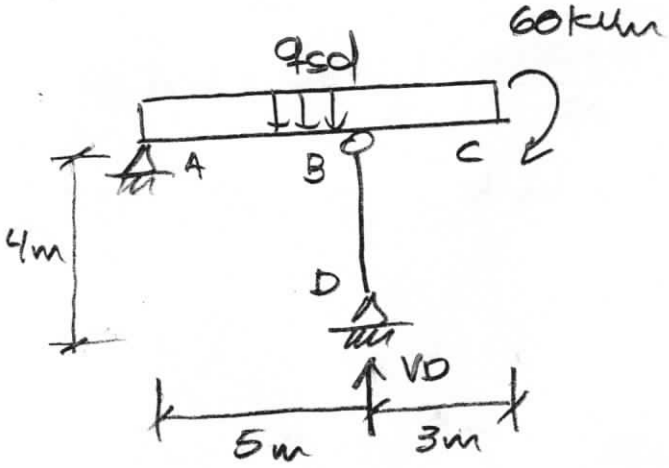
$N_{crd} = 880{,}3\,kN = V_D$

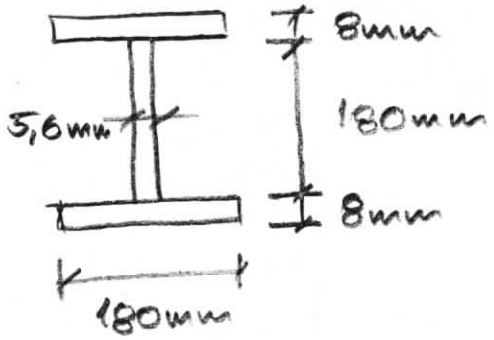
$q_{sd} = \frac{880{,}3\,kN - 140\,kN}{8{,}1} = 91{,}40\,kN/m$

$\boxed{q_{sd\,MÁX} = 91{,}40\,kN/m}$ //

AM16-BI-3002

PERFIL SOLDADO COLUNA BD





AÇO MR-250

DETERMINAR O MÁXIMO VALOR DA CARGA DISTRIBUÍDA "qsd" (EM VALOR DE CÁLCULO) DE MODO QUE A COLUNA BD ATENDA À VERIFICAÇÃO DE COMPRESSÃO SIMPLES.

→ PARA A VINCULAÇÃO IGUAL P/ AMBOS EIXOS PRINCIPAIS DE INÉRCIA BASTA A VERIFICAÇÃO DO EIXO DE MENOR INÉRCIA "EIXO Y"

$$\sum M_A = 0 \circlearrowleft^{\oplus} \quad V_D \times 5m - q_{sd} \times 8^2/_2 - 60\,kNm = 0$$

$$5V_D - 32\,q_{sd} - 60 = 0 \qquad q_{sd} = \frac{5V_D - 60}{32}$$

$V_D = N_{crd}$

→ Q = ? ELEMENTOS AA:

$$b/t_{ALMA} = 180\,mm / 5,6\,mm = 32,14$$

$$b/t_{LIM.} = 1,49 \times \sqrt{\frac{20000}{25}} = 42,14$$

$\Big\}$ $Q_a = 1$

ELEMENTOS AL:

$$b/t_{MESA} = 0,5 \times 180\,mm / 8\,mm = 11,25$$

$$Kc = \frac{4}{\sqrt{36}} = 0{,}6667$$

$$b/t\,lim = 0{,}64\sqrt{\frac{20000 \times 0{,}6667}{25}} = 14{,}78$$

$Qs = 1$

$$Q = Qa \times Qs = 1 \times 1 = 1$$

$\chi = ?$

$$I_y = \frac{18 \times 956^3}{12} + 2\left[\frac{0{,}8 \times 18^3}{12}\right] = 777{,}9\ cm^4$$

$$A_g = 18 \times 956 + 2 \times 18 \times 0{,}8 = 38{,}88\ cm^2$$

$$r_y = \sqrt{\frac{777{,}9}{38{,}88}} = 4{,}473$$

$$\lambda_y = k_y l_y / r_y = 1 \times 400\,cm / 4{,}473\,cm = 89{,}43$$

$$\lambda_0 = 89{,}43\sqrt{\frac{1 \times 25}{\pi^2 \times 20000}} = 1{,}006 < 1{,}5$$

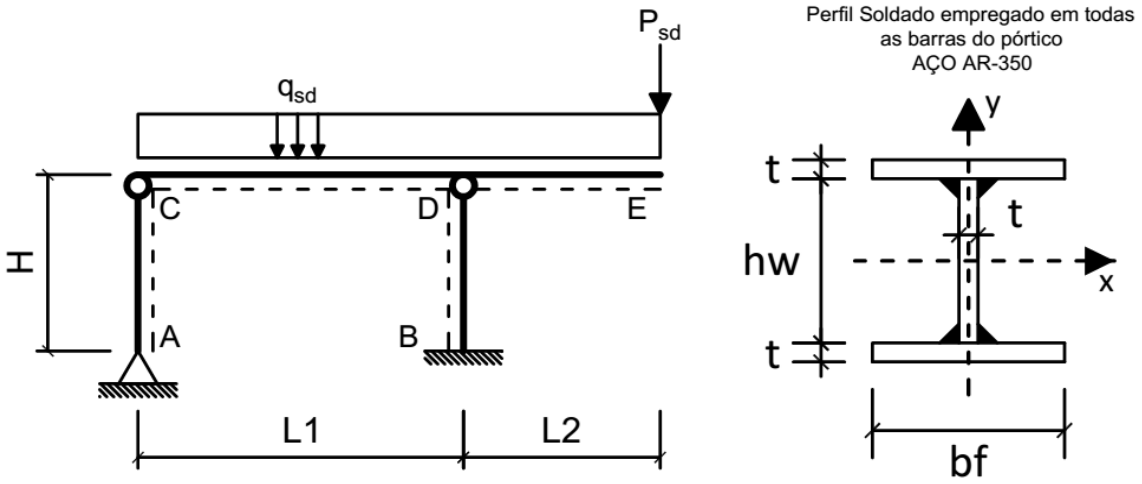
$$\chi = 0{,}658^{1{,}006^2} = 0{,}6547$$

$$N_{cRd} = Q\,\chi\,A_g\,f_y / \gamma_{a1} = \frac{1 \times 0{,}6547 \times 38{,}88\,cm^2 \times 25\,kN/cm^2}{1{,}1}$$

$$N_{cRd} = 578{,}5\ kN$$

$$q_{sd} = \frac{5 \times 578{,}5\,kN - 60}{32} = \boxed{88{,}52\ kN/m}$$

AM16-B1-4001
restart



Dados:
$H := 4.0$:
$L1 := 6.0$:
$L2 := 4.0$:
$t := 8.0$:
$bf := 250.0$:
$hw := 250.0$:
$Psd := 100.0$:
$fy := 35.0$:
$E := 20000.0$:
$\gamma a1 := 1.1$:
$\gamma a2 := 1.35$:

* Todas as cargas são permanentes;
* O perfil indicado foi aplicado na construção de todas as barras so pórtico:

a) Determinar o máximo valor de "qsd", possível de ser aplicado, de modo que a viga CDE atenda a verificação de momentos fletores desprezando as instabilidades FLA, FLM e FLT;

b) Determinar o máximo valor de "qsd", possível de ser aplicado, de modo que a coluna BD atenda a verificação de compressão simples (considerando flambagem global e local);

--> Resolução:

(1) Cálculo dos esforços internos solicitantes:

$$Msd_qsd := Psd \cdot L2 + \frac{qsd \cdot L2^2}{2}$$

$$400.00 + 8.000000000\, qsd \qquad \textbf{(1)}$$

ΣMC = 0 (horário)

$$Ncsd_qsd := solve\left(Ncsd \cdot L1 - \frac{qsd \cdot (L1 + L2)^2}{2} - Psd \cdot (L1 + L2), Ncsd \right)$$

$$8.333333333\, qsd + 166.6666667 \qquad \textbf{(2)}$$

(2) Cálculo das propriedades geométricas:

$L1_cm := 100 \cdot L1$:

$L2_cm := 100 \cdot L2$:
$H_cm := 100 \cdot H$:
$bf_cm := bf \cdot 0.1$:
$tf_cm := t \cdot 0.1$:
$hw_cm := hw \cdot 0.1$:
$tw_cm := t \cdot 0.1$:

$$Ag := 2 \cdot bf_cm \cdot tf_cm + hw_cm \cdot tw_cm$$
$$60.0000 \quad (3)$$

$$Iy := \frac{hw_cm \cdot tw_cm^3}{12} + 2 \cdot \left(\frac{tf_cm \cdot bf_cm^3}{12} \right)$$
$$2084.400000 \quad (4)$$

$$ry := \sqrt{\frac{Iy}{Ag}}$$
$$5.894064811 \quad (5)$$

$$Ky := 0.8$$
$$0.8 \quad (6)$$

$$Ly := H_cm$$
$$400.0 \quad (7)$$

$$\lambda y := \frac{Ky \cdot Ly}{ry}$$
$$54.29190385 \quad (8)$$

$$Zx := 2 \cdot \left((bf_cm \cdot tf_cm) \cdot \left(\frac{hw_cm}{2} + \frac{tf_cm}{2} \right) + \left(\frac{hw_cm}{2} \cdot tw_cm \right) \cdot \left(\frac{hw_cm}{4} \right) \right)$$
$$641.0000000 \quad (9)$$

(3) Verificação de Momentos Fletores:

$$Mrd_kNm := \frac{Zx \cdot fy}{\gamma a1} \cdot 0.01$$
$$203.9545455 \quad (10)$$
$$(11)$$

(4) Verificação de Compressão Simples:

if $\lambda y < 200$ **then** $print(\text{"Esbeltez Adequada} < 200\text{"})$ **else** $print(\text{"Esbeltez Inadequada} > 200\text{"})$ **end if**

(4.1) Verificação de Flambagem Local Elemento AA:

$$\text{bt_alma} := \frac{hw_cm}{tw_cm}$$
$$31.25000000 \quad (12)$$

$$bt_lim_alma := 1.49 \cdot \sqrt{\frac{E}{fy}}$$
$$35.61781256 \quad (13)$$

if $bt_alma < bt_lim_alma$ **then**
$Qa := 1$:
$print(\text{"Qa="}, Qa)$;

else

$$bef := \min\left(1.92 \cdot tw_cm \cdot \sqrt{\frac{E}{fy}} \cdot \left(1 - \frac{0.34}{\text{bt_alma}} \cdot \sqrt{\frac{E}{fy}} \right), hw_cm \right) :$$

$Aef := Ag - (hw_cm - bef) \cdot tw_cm$:

$Qa := \frac{Aef}{Ag}$:

print("bef=", bef, "cm");

print("Aef=", Aef, "cm2");

print("Qa=", Qa);

end if:

"Qa=", 1 **(14)**

(4.2) Verificação de Flambagem Local Elemento AL:

$$\text{bt_mesa} := \frac{0.5 \cdot bf_cm}{tf_cm}$$

15.62500000 **(15)**

$$kc := \frac{4}{\sqrt{\frac{hw_cm}{tw_cm}}}$$

0.7155417528 **(16)**

if $kc > 0.76$ **then** $kc := 0.76$ **end if**

if $kc < 0.35$ **then** $kc := 0.35$ **end if**

$$bt_lim_mesa := 0.64 \cdot \sqrt{\frac{E}{\left(\frac{fy}{kc}\right)}}$$

12.94131594 **(17)**

$$bt_lim_elast_mesa := 1.17 \cdot \sqrt{\frac{E}{\left(\frac{fy}{kc}\right)}}$$

23.65834321 **(18)**

if $bt_mesa < bt_lim_mesa$ **then**

$Qs := 1$:

print("Qs=", Qs);

elif $bt_mesa < bt_lim_elast_mesa$ **then**

$Qs := 1.415 - 0.65 \cdot bt_mesa \cdot \sqrt{\frac{fy}{kc \cdot E}}$:

print("Qs=", Qs);

else

$Qs := \frac{0.90 \cdot E \cdot kc}{fy \cdot (bt_mesa)^2}$:

print("Qs=", Qs);

end if:

"Qs=", 0.9127326858 **(19)**

$Q := Qa \cdot Qs$

0.9127326858 **(20)**

(4.3) Verificação de Flambagem Global:

$$\lambda 0y := \lambda y \cdot \sqrt{\frac{Q \cdot fy}{\pi^2 \cdot E}}$$

0.6906786386 **(21)**

if $\lambda 0y \leq 1.5$ **then** $Xy := 0.658^{\lambda 0y^2}$ **else** $Xy := \frac{0.877}{\lambda 0y^2}$ **end if**:

$print(\text{"Xy="}, Xy)$

"Xy=", 0.8190058973 **(22)**

$$Ncrdy := \frac{Q \cdot Xy \cdot Ag \cdot fy}{\gamma a1} :$$

$print(\text{"Ncrdy="}, Ncrdy, \text{"kN"})$

"Ncrdy=", 1427.109318, "kN" **(23)**

Máximos qsd:

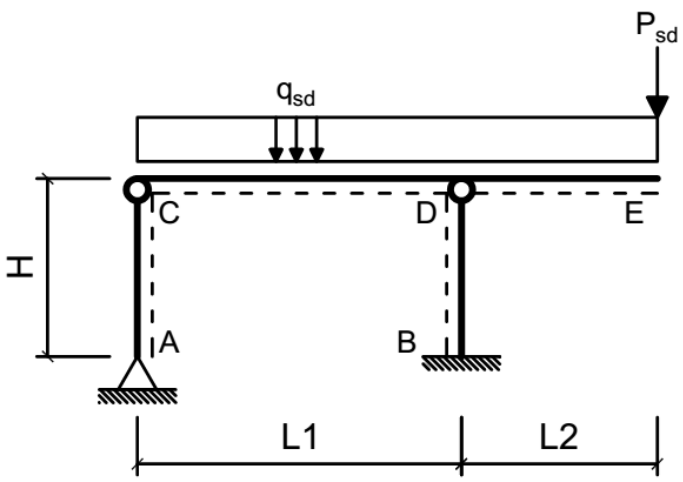
$qsd_viga := solve(\text{Msd_qsd} - \text{Mrd_kNm} = 0, \text{qsd})$

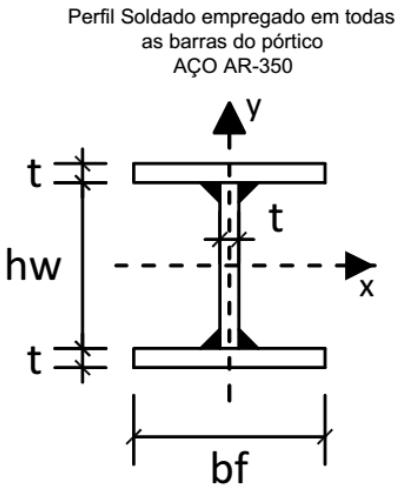
-24.50568181 **(24)**

$\text{qsd_coluna} := solve(\text{Ncsd_qsd} - \text{Ncrdy} = 0, \text{qsd})$

151.2531181 **(25)**

AM16-B1-4002
restart





Dados:
$H := 5.0$:
$L1 := 5.0$:
$L2 := 4.0$:
$t := 12.5$:
$bf := 300.0$:
$hw := 350.0$:
$qsd := 5.0$:
$fy := 35.0$:
$E := 20000.0$:
$\gamma a1 := 1.1$:
$\gamma a2 := 1.35$:

* Todas as cargas são permanentes;
* O perfil indicado foi aplicado na construção de todas as barras so pórtico:

a) Determinar o máximo valor de "Psd", possível de ser aplicado, de modo que a viga CDE atenda a
verificação de momentos fletores desprezando as instabilidades FLA, FLM e FLT;

b) Determinar o máximo valor de "Psd", possível de ser aplicado, de modo que a coluna BD atenda a
verificação de compressão simples (considerando flambagem global e local);

--> Resolução:

(1) Cálculo dos esforços internos solicitantes:

$$Msd_Psd := P_sd \cdot L2 + \frac{qsd \cdot L2^2}{2}$$

$$4.0\ P_sd + 40.00000000 \quad \textbf{(1)}$$

ΣMC = 0 (horário)

$$Ncsd_Psd := solve\left(Ncsd \cdot L1 - \frac{qsd \cdot (L1 + L2)^2}{2} - P_sd \cdot (L1 + L2) = 0, Ncsd\right)$$

$$40.50000000 + 1.800000000\ P_sd \quad \textbf{(2)}$$

(2) Cálculo das propriedades geométricas:

$L1_cm := 100 \cdot L1$:
$L2_cm := 100 \cdot L2$:
$H_cm := 100 \cdot H$:
$bf_cm := bf \cdot 0.1$:
$tf_cm := t \cdot 0.1$:
$hw_cm := hw \cdot 0.1$:
$tw_cm := t \cdot 0.1$:

$$Ag := 2 \cdot bf_cm \cdot tf_cm + hw_cm \cdot tw_cm$$

$$118.7500 \quad \textbf{(3)}$$

$$Iy := \frac{hw_cm \cdot tw_cm^3}{12} + 2 \cdot \left(\frac{tf_cm \cdot bf_cm^3}{12}\right)$$

$$5630.696615 \quad \textbf{(4)}$$

$$ry := \sqrt{\frac{Iy}{Ag}}$$

$$6.885956183 \quad \textbf{(5)}$$

$$Ky := 0.8$$

$$0.8 \quad \textbf{(6)}$$

$$Ly := H_cm$$

$$500.0 \quad \textbf{(7)}$$

$$\lambda y := \frac{Ky \cdot Ly}{ry}$$

$$58.08924561 \quad \textbf{(8)}$$

$$Zx := 2 \cdot \left((bf_cm \cdot tf_cm) \cdot \left(\frac{hw_cm}{2} + \frac{tf_cm}{2}\right) + \left(\frac{hw_cm}{2} \cdot tw_cm\right) \cdot \left(\frac{hw_cm}{4}\right) \right)$$

$$1742.187500 \quad \textbf{(9)}$$

(3) Verificação de Momentos Fletores:

$$Mrd_kNm := \frac{Zx \cdot fy}{\gamma a1} \cdot 0.01$$

$$554.3323864 \quad \textbf{(10)}$$

(11)

(4) Verificação de Compressão Simples:

if $\lambda y < 200$ **then** *print*("Esbeltez Adequada < 200") **else** *print*("Esbeltez Inadequada > 200") **end if**

"Esbeltez Adequada < 200" **(12)**

(4.1) Verificação de Flambagem Local Elemento AA:

$$\text{bt_alma} := \frac{hw_cm}{tw_cm}$$

28.00000000 **(13)**

$$bt_lim_alma := 1.49 \cdot \sqrt{\frac{E}{fy}}$$

35.61781256 **(14)**

if *bt_alma* < *bt_lim_alma* **then**
Qa := 1 :
print("Qa=", *Qa*);

else

$$bef := \min\left(1.92 \cdot tw_cm \cdot \sqrt{\frac{E}{fy}} \cdot \left(1 - \frac{0.34}{\text{bt_alma}} \cdot \sqrt{\frac{E}{fy}}\right), hw_cm\right) :$$

$$Aef := Ag - (hw_cm - bef) \cdot tw_cm :$$

$$Qa := \frac{Aef}{Ag} :$$

print("bef=", *bef*, "cm");
print("Aef=", *Aef*, "cm2");
print("Qa=", *Qa*);
end if:

"Qa=", 1 **(15)**

(4.2) Verificação de Flambagem Local Elemento AL:

$$\text{bt_mesa} := \frac{0.5 \cdot bf_cm}{tf_cm}$$

12.00000000 **(16)**

$$kc := \frac{4}{\sqrt{\frac{hw_cm}{tw_cm}}}$$

0.7559289460 **(17)**

if $kc > 0.76$ **then** $kc := 0.76$ **end if**
if $kc < 0.35$ **then** $kc := 0.35$ **end if**

$$bt_lim_mesa := 0.64 \cdot \sqrt{\frac{E}{\left(\frac{fy}{kc}\right)}}$$

13.30152508 **(18)**

$$bt_lim_elast_mesa := 1.17 \cdot \sqrt{\frac{E}{\left(\frac{fy}{kc}\right)}}$$

24.31685053 **(19)**

if $bt_mesa < bt_lim_mesa$ **then**
$Qs := 1$:
$print(\text{"Qs="}, Qs)$;

elif $bt_mesa < bt_lim_elast_mesa$ **then**
$Qs := 1.415 - 0.65 \cdot bt_mesa \cdot \sqrt{\frac{fy}{kc \cdot E}}$:
$print(\text{"Qs="}, Qs)$;
else

$Qs := \frac{0.90 \cdot E \cdot kc}{fy \cdot (bt_mesa)^2}$:
$print(\text{"Qs="}, Qs)$;
end if:

"Qs=", 1 **(20)**

$Q := Qa \cdot Qs$

1 **(21)**

(4.3) Verificação de Flambagem Global:

$$\lambda 0y := \lambda y \cdot \sqrt{\frac{Q \cdot fy}{\pi^2 \cdot E}}$$

0.7735081395 **(22)**

if $\lambda 0y \le 1.5$ **then** $Xy := 0.658^{\lambda 0y^2}$ **else** $Xy := \frac{0.877}{\lambda 0y^2}$ **end if**:

$print(\text{"Xy="}, Xy)$

"Xy=", 0.7784699525 **(23)**

$Ncrdy := \frac{Q \cdot Xy \cdot Ag \cdot fy}{\gamma a1}$:
$print(\text{"Ncrdy="}, Ncrdy, \text{"kN"})$

"Ncrdy=", 2941.377945, "kN" **(24)**

Máximos qsd:

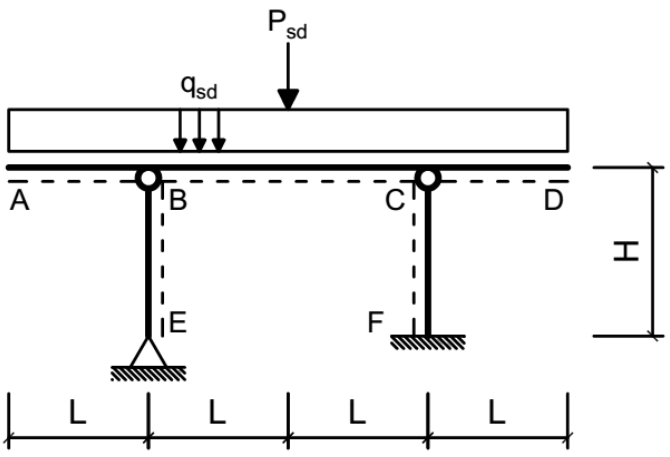
$Psd_viga := solve(\text{Msd_Psd} - \text{Mrd_kNm} = 0, \text{P_sd})$

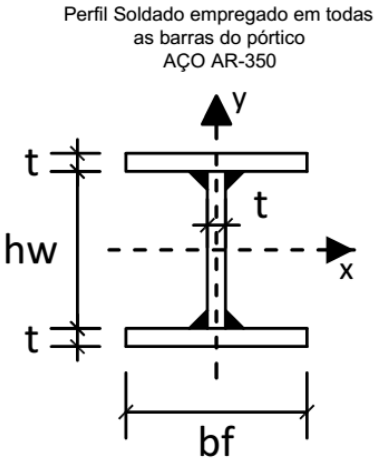
128.5830966 **(25)**

$$Psd_coluna := solve(Ncsd_Psd - Ncrdy = 0, P_sd)$$

$$1611.598858 \quad \textbf{(26)}$$

AM16-B1-4003
restart





Dados:
$H := 4.0$:
$L := 4.0$:
$t := 9.5$:
$bf := 200.0$:
$hw := 350.0$:
$qsd := 25.0$:
$fy := 35.0$:
$E := 20000.0$:
$\gamma a1 := 1.1$:
$\gamma a2 := 1.35$:

* Todas as cargas são em valor de cálculo;
* O perfil indicado foi aplicado na construção de todas as barras so pórtico:

Determinar o máximo valor da carga "Psd", possível de ser aplicada, de modo que:

a) A viga ABCD atenda a verificação de momentos fletores desprezando as instabilidades FLA, FLM e FLT;

b) A coluna BE atenda a verificação de compressão simples (considerando flambagem global e local);

--> Resolução:

(1) Cálculo dos esforços internos solicitantes:

$$Msd_A := -\frac{qsd \cdot L^2}{2}$$

-200.0000000 **(1)**

$$Ncsd_Psd := \frac{(qsd \cdot 4\,L + P_sd)}{2}$$

$$200.00 + \frac{1}{2}\,P_sd \tag{2}$$

$$Msd_BC := -\frac{qsd \cdot (2 \cdot L)^2}{2} + Ncsd \cdot L$$

$$2.000000000\,P_sd \tag{3}$$

(2) Cálculo das propriedades geométricas:

$L_cm := 100 \cdot L$:
$H_cm := 100 \cdot H$:
$bf_cm := bf \cdot 0.1$:
$tf_cm := t \cdot 0.1$:
$hw_cm := hw \cdot 0.1$:
$tw_cm := t \cdot 0.1$:

$$Ag := 2 \cdot bf_cm \cdot tf_cm + hw_cm \cdot tw_cm$$

$$71.2500 \tag{4}$$

$$Iy := \frac{hw_cm \cdot tw_cm^3}{12} + 2 \cdot \left(\frac{tf_cm \cdot bf_cm^3}{12} \right)$$

$$1269.167344 \tag{5}$$

$$ry := \sqrt{\frac{Iy}{Ag}}$$

$$4.220530180 \tag{6}$$

$$Ky := 0.8$$

$$0.8 \tag{7}$$

$$Ly := H_cm$$

$$400.0 \tag{8}$$

$$\lambda y := \frac{Ky \cdot Ly}{ry}$$

$$75.81985825 \tag{9}$$

$$Zx := 2 \cdot \left((bf_cm \cdot tf_cm) \cdot \left(\frac{hw_cm}{2} + \frac{tf_cm}{2} \right) + \left(\frac{hw_cm}{2} \cdot tw_cm \right) \cdot \left(\frac{hw_cm}{4} \right) \right)$$

$$973.9875000 \tag{10}$$

(3) Verificação de Momentos Fletores:

$$Mrd_kNm := \frac{Zx \cdot fy}{\gamma a1} \cdot 0.01$$

$$309.9051136 \tag{11}$$

(12)

(4) Verificação de Compressão Simples:

if $\lambda y < 200$ **then** *print*("Esbeltez Adequada < 200") **else** *print*("Esbeltez Inadequada > 200") **end if**

"Esbeltez Adequada < 200" **(13)**

(4.1) Verificação de Flambagem Local Elemento AA:

$$\text{bt_alma} := \frac{hw_cm}{tw_cm}$$

36.84210526 **(14)**

$$bt_lim_alma := 1.49 \cdot \sqrt{\frac{E}{fy}}$$

35.61781256 **(15)**

if *bt_alma* < *bt_lim_alma* **then**
Qa := 1 :
print("Qa=", *Qa*);

else

$$bef := \min\left(1.92 \cdot tw_cm \cdot \sqrt{\frac{E}{fy}} \cdot \left(1 - \frac{0.34}{\text{bt_alma}} \cdot \sqrt{\frac{E}{fy}}\right), hw_cm\right) :$$

$$Aef := Ag - (hw_cm - bef) \cdot tw_cm :$$

$$Qa := \frac{Aef}{Ag} :$$

print("bef=", *bef*, "cm");
print("Aef=", *Aef*, "cm2");
print("Qa=", *Qa*);
end if:

"bef=", 33.98313151, "cm"
"Aef=", 70.28397493, "cm2"
"Qa=", 0.9864417534 **(16)**

(4.2) Verificação de Flambagem Local Elemento AL:

$$\text{bt_mesa} := \frac{0.5 \cdot bf_cm}{tf_cm}$$

10.52631579 **(17)**

$$kc := \frac{4}{\sqrt{\frac{hw_cm}{tw_cm}}}$$

0.6590035768 **(18)**

if *kc* > 0.76 **then** *kc* := 0.76 **end if**
if *kc* < 0.35 **then** *kc* := 0.35 **end if**

$$bt_lim_mesa := 0.64 \cdot \sqrt{\frac{E}{\left(\frac{fy}{kc}\right)}}$$

12.41952070 **(19)**

$$bt_lim_elast_mesa := 1.17 \cdot \sqrt{\frac{E}{\left(\frac{fy}{kc}\right)}}$$

22.70443628 **(20)**

if $bt_mesa < bt_lim_mesa$ **then**
$Qs := 1$:
$print(\text{"Qs="}, Qs)$;

elif $bt_mesa < bt_lim_elast_mesa$ **then**
$Qs := 1.415 - 0.65 \cdot bt_mesa \cdot \sqrt{\frac{fy}{kc \cdot E}}$:
$print(\text{"Qs="}, Qs)$;
else

$Qs := \frac{0.90 \cdot E \cdot kc}{fy \cdot (bt_mesa)^2}$:
$print(\text{"Qs="}, Qs)$;
end if:

"Qs=", 1 **(21)**

$Q := Qa \cdot Qs$

0.9864417534 **(22)**

(4.3) Verificação de Flambagem Global:

$$\lambda 0y := \lambda y \cdot \sqrt{\frac{Q \cdot fy}{\pi^2 \cdot E}}$$

1.002738853 **(23)**

if $\lambda 0y \le 1.5$ **then** $Xy := 0.658^{\lambda 0y^2}$ **else** $Xy := \frac{0.877}{\lambda 0y^2}$ **end if**:

$print(\text{"Xy="}, Xy)$

"Xy=", 0.6564910732 **(24)**

$Ncrdy := \frac{Q \cdot Xy \cdot Ag \cdot fy}{\gamma a1}$:
$print(\text{"Ncrdy="}, Ncrdy, \text{"kN"})$

"Ncrdy=", 1468.116432, "kN" **(25)**

Máximos qsd:

$Psd_viga1 := solve(\text{Msd_BC} - \text{Mrd_kNm} = 0, \text{P_sd})$

154.9525568 **(26)**

$\text{Psd_coluna} := solve(\text{Ncsd_Psd} - \text{Ncrdy} = 0, \text{P_sd})$

2536.232864 **(27)**