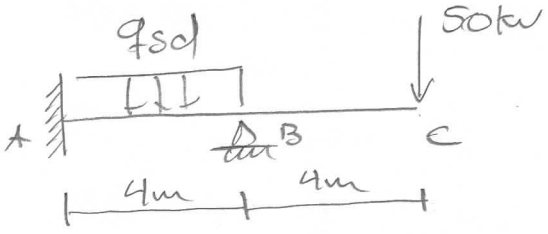
B2AM07ANA

- PERFIL ISADO:
- $b_f = 220\,mm$ $t_f = t_w = 8\,mm$
  $h_w = 334\,mm$;
- VIGA CONTIDA LATERALMENTE;
- AÇO 350;



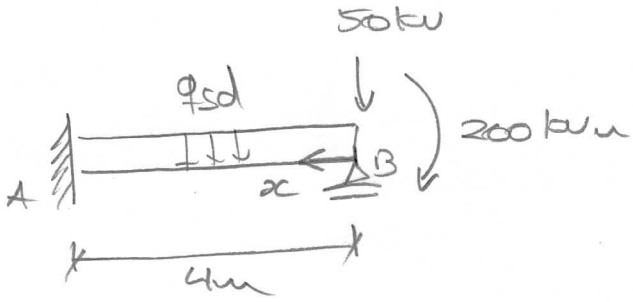
QUAL MÁXIMA CARGA qsd (EM VALOR DE CÁLCULO) POSSÍVEL DE SER APLICADA DE MODO QUE SEJA ATENDIDA:

Q01) A VERIF. FLM Q02) A VERIF. FLA Q03) A VERIF DE CORTE

① Solicitações

$M_B = 50kN \times 4m = 200\,kN.m$

$V_B^{dir} = 50kN$



$$\delta_{BA}(x) = \frac{qL^4}{48EI}\left(2\left(\frac{x}{L}\right)^4 - 3\left(\frac{x}{L}\right)^3 + \left(\frac{x}{L}\right)\right) - \frac{ML^2}{4EI}\left(\left(\frac{x}{L}\right)^3 - 2\left(\frac{x}{L}\right)^2 + \left(\frac{x}{L}\right)\right)$$

$$\delta_{BA}(x) = \frac{q}{EI}\left(\frac{x^4}{24} - \frac{x^3}{4} + \frac{4}{3}x\right) - \frac{1}{EI}\left(\frac{25x^3}{2} - 100x^2 + 200x\right)$$

$$\theta_{BA}(x) = \frac{d\delta_{BA}(x)}{dx} = \frac{q}{EI}\left(\frac{x^3}{6} - \frac{3}{4}x^2 + \frac{4}{3}\right) - \frac{1}{EI}\left(\frac{75}{2}x^2 - 200x + 200\right)$$

$$M_{BA}(x) = \frac{d\theta_{BA}(x)}{dx} \times EI$$

$$= q\left(\frac{x^2}{2} - \frac{3}{2}x\right) - 75x + 200$$

$$V_{BA}(x) = \frac{dM_{BA}(x)}{dx} = q\left(x - \frac{3}{2}\right) - 75$$

$M_{BA}(x) = q\left(\frac{x^2}{2} - \frac{3}{2}x\right) - 75x + 200$

$V_{BA}(x) = q\left(x - \frac{3}{2}\right) - 75$

$M_A = \underline{200 \text{ kN.m}}$ ↺

$M_B = q\left(\frac{4^2}{2} - \frac{3}{2}\cdot 4\right) - 75.4 + 200 = \underline{2q - 100}$ //

$V_A = q\left(0 - \frac{3}{2}\right) - 75 = \underline{-1{,}5q - 75}$ // ?

$V_B = q\left(4 - \frac{3}{2}\right) - 75 = \underline{+2{,}5q - 75}$ // ?

(2) VERIF. FLM

$\lambda_{MESH} = 0{,}5 \times 220/8 = 13{,}75$

$\lambda_{PMESH} = 0{,}38\sqrt{\frac{20000}{35}} = 9{,}0837$

M_{ESH} SEMI COMPACT

$k_c = 4/\sqrt{334/8} = 0{,}61906$

$\lambda_{rMESH} = 0{,}95\sqrt{\frac{0{,}61906 \times 20000}{0{,}7 \times 35}} = 21{,}356$

$Z_x = 825{,}03 \text{ cm}^3$ $\quad W_x = 730{,}21 \text{ cm}^3$

$M_{pl} = 825{,}03 \times 35 = 28876 \text{ kN.m}$

$M_r = 730{,}21 \times 0{,}7 \times 35 = 17890 \text{ kN.m}$

$$M_{Rd} = \frac{1}{1{,}1}\left[(28876 - (28876 - 17890)\frac{(13{,}75 - 9{,}0837)}{(21{,}356 - 9{,}0837)}\right]$$

$M_{Rd} = \underline{2245{,}3 \text{ kN.m}}$ //

COND. LIMITE : $M_{Sd} = M_{Rd}$

$2q - 100 = 224{,}53 \text{ kN.m}$

$q = \frac{224{,}53 + 100}{2} = \underline{\boxed{162{,}27 \text{ kN/m}}}$ // Q01 //

③ VERIF. FLA

$\lambda_{AMA} = 334/8 = 41,75$ — ALMA COMPACTA

$\lambda_{pAMA} = 3,76\sqrt{\frac{20000}{35}} = 89,88$

$M_{Rd} = M_{el}/\gamma_{a1} = \frac{28876\ kNcm}{1,1} = 262,51\ kNcm$

COND. LIMITE $M_{Sd} = M_{Rd}$

$2q - 100 = 262,51 \qquad q = \frac{262,51+100}{2} = \boxed{181,26\ kN/m}$

Q02 ✓

④ VERIF DE CORTANTES

$\lambda_{as} = 41,75 \qquad \lambda_{pas} = 1,10\sqrt{\frac{5\times20000}{35}} = 58,797$

ALMA COMPACTA P/ CISALHAMENTO

$V_{pl} = 0,60 \times 35 \times (33,4 \times 2 \times 0,8) \times 0,8 = 588\ kN$

$V_{Rd} = 588/1,1 = 534,55\ kN$

COND. LIMITE: $V_{Sd} = V_{Rd}$

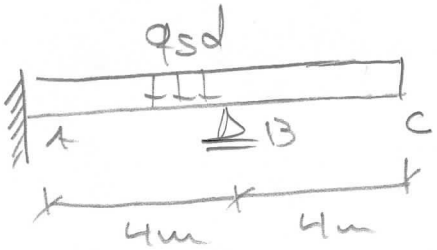
$+1,5q + 75 = 534,55$

$q = \frac{534,55 - 75}{1,5} = 306,37\ kN/m$

$2,5q - 75 = 534,55$

$q = (534,55 + 75)/2,5 = \boxed{243,82\ kN/m}$ Q03 ✓

B2AM07AM1



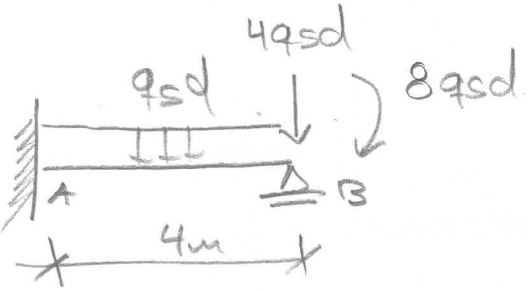
- PERFIL SOLDADO I
  $b_f = 220mm \quad t_f = t_w = 8mm$
  $h_w = 334mm$
- VIGA CONTIDA LATERALMENTE;
- AÇO AR350;

Q01) q_{sd} P/ FLM; Q02) q_{sd} P/ FLA; Q03) q_{sd} P/ CORTE;

① SOLICITAÇÕES:

$M_B = q_{sd} \times 4^2/2 = 8q_{sd}$

$V_B^{ESQ} = q_{sd} \times 4 = 4q_{sd}$



$$\delta_{BA}(x) = \frac{qL^4}{48EI}\left(2(x/L)^4 - 3(x/L)^3 + x/L\right) - \frac{ML^2}{4EI}\left((x/L)^3 - 2(x/L)^2 + x/L\right)$$

$$\delta_{BA}(x) = \frac{q_{sd} \times 4^4}{48EI}\left(\frac{2}{256}x^4 - \frac{3}{64}x^3 + x/4\right) - \frac{8q_{sd} \times 4^2}{4EI}\left(x^3/64 - 2/16\,x^2 + x/4\right)$$

$$\delta_{BA}(x) = \frac{q_{sd}}{EI}\,1/24\left(x^4 - 18x^3 + 96x^2 - 160x\right)$$

$$\theta_{BA}(x) = \frac{d\delta_{BA}(x)}{dx} = \frac{q_{sd}}{EI}\,1/12\left(2x^3 - 27x^2 + 96x - 80\right)$$

$$M_{BA}(x) = \frac{d\theta_{BA}(x)EI}{dx} = q_{sd}/2\left(x^2 - 9x + 16\right)$$

$V_{BA}(x) = q_{sd}/2\,(2x - 9)$

$V_B = q_{sd}/2\,(2.0 - 9) = \underline{-4{,}5\,q_{sd}}$ // MÁXIMO CORTE

$V_A = q_{sd}/2\,(2\times 4 - 9) = -0{,}5\,q_{sd}$

$M_B = q_{sd}/2\,(0^2 - 9\times 0 + 16) = \underline{+8\,q_{sd}}$ // MÁXIMO MOMENTO

$M_A = q_{sd}/2\,(4^2 - 9\times 4 + 16) = -2\,q_{sd}$

(2) VERIF. FLM:

$\lambda_{MESA} = 0{,}5 \times 220/8 = 13{,}75$ MESA

$\lambda_{pMESA} = 0{,}38\sqrt{\frac{20000}{35}} = 9{,}0837$ SEMICOMPACTA

$k_c = 4/\sqrt{334/8} = 0{,}61906$

$\lambda_{rMESA} = 0{,}95\sqrt{\frac{0{,}61906\times 20000}{0{,}7\times 35}} = 21{,}356$

$Z_x = 825{,}03\ cm^3$ $\quad W_x = 730{,}21\ cm^3$

$M_{pl} = 825{,}03 \times 35 = 28876\ kN\,cm$

$M_r = 730{,}21 \times 0{,}7 \times 35 = 17890\ kN\,cm$

$$M_{Rd} = \frac{1}{1{,}1}\left(28876 - (28876 - 17890)\frac{(13{,}75 - 9{,}0837)}{(21{,}356 - 9{,}0837)}\right)$$

$M_{Rd} = \underline{22453\ kN\,cm}$ //

COND. LIMITE: $M_{sd} = M_{Rd}$

$8\,q_{sd} = 224{,}53\ kN\,m$

$q_{sd} = \frac{224{,}53\ kN\,m}{8} = \boxed{28{,}066\ kN/m}$ Q01 //

(3) VERIF. FLA

$\lambda_{ALMA} = 334/8 = 41{,}75$ ALMA COMPACTA

$\lambda_{PALMA} = 3{,}76\sqrt{\frac{20000}{35}} = 89{,}88$

$M_{Rd} = M_{Rl}/\gamma_{a1} = \frac{28876\,kN.cm}{1{,}1} = 26251\,kN.cm = 262{,}51\,kN.m$

COND. LIMITE: $M_{Sd} = M_{Rd}$

$4{,}5\,q_{sd} = 262{,}51\,kN/m$ $\quad q_{sd} = 262{,}51/4{,}5 = \boxed{58{,}336\,kN/m}$

Q02 //

(4) VERIF. DE CORTANTES

$\lambda_{cs} = 41{,}75$ $\quad \lambda_{Pcs} = 1{,}10\sqrt{\frac{5\times 20000}{35}} = 58{,}797$

ALMA COMPACTA P/ CISALHAMENTO

$V_{pl} = 0{,}60 \times 35 \times (33{,}4 + 2\times 0{,}8) \times 0{,}8 = 588\,kN$

$V_{Rd} = V_{pl}/\gamma_{a1} = 588/1{,}1 = 534{,}55\,kN$

COND. LIMITE: $V_{Sd} = V_{Rd}$

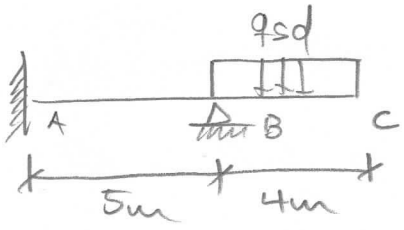
$8{,}5\,q_{sd} = 534{,}55\,kN$

$q_{sd} = 534{,}55/8{,}5 = \boxed{62{,}887\,kN/m}$ //

Q03 //

BRAMOTANB

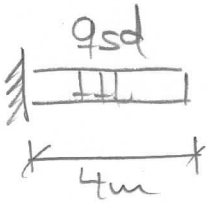
- PERFIL I SOLDADO AR 350
- $b_f = 230\,mm$ $h_w = 320\,mm$
  $t_f = 12\,mm$ $t_w = 8\,mm$
- VIGA CONTIDA LATERALMENTE
- CARGA q_{sd} JÁ EM VALOR DE CÁLCULO;



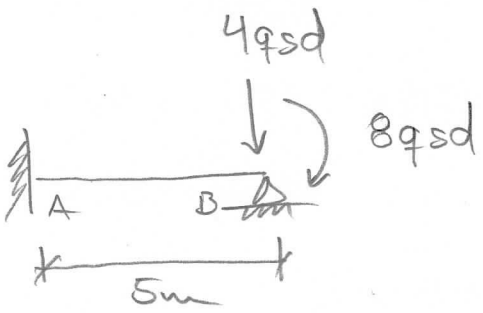
PEDE-SE: QUAL A MAIOR CARGA q_{sd} (EM kN/m) POSSÍVEL DE SER APLICADA DE MODO QUE SEJA ATENDIDA A VERIFICAÇÃO:

Q01) FLA Q02) FLM Q03) CORTANTES

① Solicitações



$$M_B = q_{sd}\,4^2/2 = 8q_{sd}$$
$$V_B = q_{sd} \times 4 = 4q_{sd}$$



$$\delta_{BA}(x) = \frac{ML^2}{4EI}\left(\left(\frac{x}{L}\right)^3 - 2\left(\frac{x}{L}\right)^2 + \frac{x}{L}\right)$$

$$\frac{d\delta_{BA}(x)}{dx} = \theta_{BA}(x) = \frac{ML^2}{4EI}\left(3x^2/L^3 - 4x/L^2 + 1/L\right)$$

$$M_{BA}(x) = EI\,\frac{d\theta_{BA}(x)}{dx} = \frac{ML^2}{4}\left(6x/L^3 - 4/L^2\right)$$

$$M_{BA}(x) = 8q_{sd} \cdot 5^2/4\left(6x/5^3 - 4/5^2\right)$$

$$M_{BA}(x) = q_{sd}\left(12/5\,x - 8\right)$$

$$V_{BA}(x) = q_{sd} \times 12/5$$

MÁXIMO CORTANTE: $V_{sd}^{ESQ} = 12/5\ q_{sd}$

$V_{sd}^{DIR} = 4\ q_{sd}$

MÁXIMO MOMENTO:

$M_B = q_{sd}(12/5 \cdot 0 - 8) = -8\ q_{sd}$ (EMPOTRADO)

$M_A = q_{sd}(12/5 \cdot 5 - 8) = 4\ q_{sd}$

(2) FLA: $\lambda_{ALMA} = 320mm/8mm = 40$ } ALMA COMPACTA

$\lambda_{PALMA} = 3{,}76\sqrt{\frac{20000}{35}} = 89{,}88$

$Z_{3x} = 1121{,}1\ cm^3$ $\quad M_{Rd} = M_{Rd}/\gamma_{a1} = Z_x \cdot f_y/\gamma_{a1}$

$W_x = 1011{,}7\ cm^3$

$M_{Rd} = 1121{,}1 \times 35/1{,}1 = 35671\ kN\,cm$

COND. LIMITE $\Rightarrow M_{sd} = M_{Rd}$

$8\ q_{sd} = 356{,}71\ kN\,m$ $\quad q_{sd} = 356{,}71/8$

$q_{sd\,FLA} = \boxed{44{,}589\ kN/m}$ (Q01)

(3) FLM: $\lambda_{MESA} = 0{,}5 \times 230mm/12mm = 9{,}5833$

$\lambda_{PMESA} = 0{,}38\sqrt{\frac{20000}{35}} = 9{,}0837$

$\lambda_{rMESA} = 0{,}95\sqrt{\frac{k_c E}{0{,}7 f_y}} = 0{,}95\sqrt{\frac{0{,}63246 \times 20000}{0{,}7 \times 35}} = 21{,}586$

$k_c = 4/\sqrt{40} = 0{,}63246$ MESA SEMICOMPACTA

$M_R = W_x \cdot 0{,}7 f_y = 1011{,}7 \times 0{,}7 \times 35 = 24787\ kN\,cm$

$$M_{Rd} = \frac{1}{1,1}\left(35671 - (35671-24787)\frac{(9,5833-9,0837)}{(21,586-9,0837)}\right)$$

$M_{Rd} = 35147 \text{ kN.m}$

COND. LIMITE $\Rightarrow$ $M_{sd} = M_{Rd}$

$8 q_{sd} = 351,47 \text{ kN.m}$ $\quad q_{sd} = 351,47/8 = \boxed{43,934 \text{ kN/m}}$ (Q02)

(4) VERIF. DE CORTURES :

$\lambda_{ais} = 40$

$\lambda_{p\,ais} = 1,10\sqrt{\frac{5 \times 20000}{35}} = 58,797$ } ALMA COMPACTA P/ CISALHAMENTO

$V_{Rd} = 0,6 \times (h_w + 24) \cdot t_w \times f_y / \gamma_{a1}$

$V_{Rd} = 0,6 \times (32 + 2 \times 1,2) \times 0,8 \times 35/1,1 = 525,38 \text{ kN}$

COND. LIMITE $\Rightarrow$ $V_{sd} = V_{Rd}$

$4 q_{sd} = 525,38 \text{ kN}$

$q_{sd} = 1/4 \times 525,38 = \boxed{131,35 \text{ kN/m}}$ (Q03)

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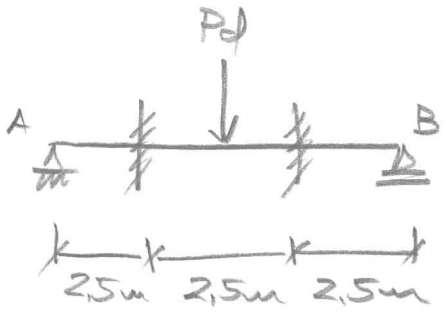
PEDE-SE: MÁXIMO VALOR DE Pd QUE AINDA ATENDA FLT;



- A86; TRAVAMENTO LATERAL A CADA TERÇO DO VÃO; CARGA Pd NO MEIO DO VÃO;
- PERFIL I SOLDADO

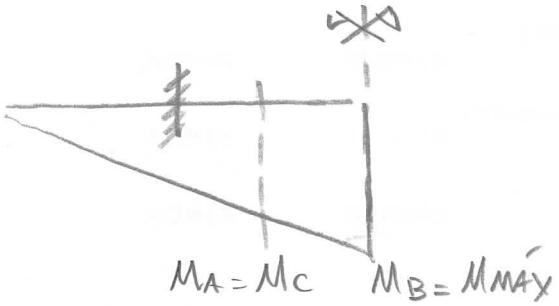
$b_f = 220\,mm$
$t_f = 16\,mm$
$h_w = 320\,mm$
$t_w = 8\,mm$

$V_A = V_B = Pd/2$ $\quad M(x) = Pd/2\,x$

PELA SIMETRIA:

$M_A = Pd/2 \times (2,5 + 1/4 \times 2,5) = 1,5625\,Pd$

$M_B = Pd/2 \times (2,5 + 1/2 \times 2,5) = 1,875\,Pd$



$$C_b = \frac{12,5 \times 1,875}{2,5 \times 1,875 + 3 \times 1,5625 + 4 \times 1,875 + 3 \times 1,5625} = 1,0870$$

$I_x = 22069\,cm^4$ $\quad I_y = 2849,8\,cm^4$ $\quad r_y = 5,4399\,cm$

$W_x = 1253,9\,cm^3$ $\quad W_y = 258,26\,cm^3$ $\quad J = 65,54\,cm^4$

$\beta_1 = 0,02821/cm$ $\quad C_w = 801787\,cm^6$ $\quad Z_x = 1387,5\,cm^3$

$\lambda_{FLT} = L_b/r_y = 250cm/5,4399cm = 45,956$

$\lambda_{pFLT} = 1,76\sqrt{\frac{20000}{25}} = 49,780$

NÃO OCORRE FLT

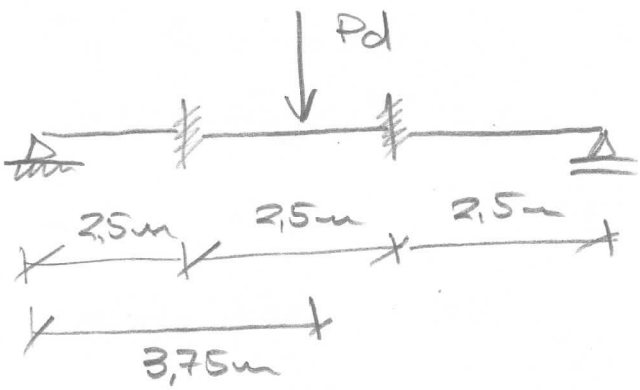
$M_{Rd} = Z_x \cdot f_y/\gamma_{a1} = 1387,5\,cm^3 \times 25\,kN/cm^2/1,1 = 31534\,kN\,cm = 315,34\,kN\,m$

$M_{Sd} = M_{Rd} \rightarrow 1,875\,P_{Sd} = 315,34 \Rightarrow P_{Sd} = 168,18\,kN$

B2AM08AMA 12 PONTOS - PERFIL I SOLDADO:

$b_f = 200\,mm$ $t_f = 16\,mm$

$h_w = 300\,mm$ $t_w = 8\,mm$



- AÇO MR 250
- TRAVAMENTO LATERAL A CADA TERÇO DO VÃO
- DESPREZAR O PESO PRÓPRIO DA VIGA;

PEDE-SE: MÁXIMA Pd (EM VALOR DE CÁLCULO) P/ QUE SEJA ATENDIDA A VERIFICAÇÃO FLT;

1 SOLICITAÇÃO $M(x) = Pd/2 \cdot x$ (FAZENDO $Pd = 1$)

TRECHO 0 - 2,5:

$M_A = 1/2 \cdot (1/4 \times 2{,}5) = 0{,}3125$

$M_B = 1/2 \cdot (2/4 \times 2{,}5) = 0{,}625$

$M_C = 1/2 \cdot (3/4 \times 2{,}5) = 0{,}9375$

$M_{MÁX} = 1/2 \cdot (4/4 \times 2{,}5) = 1{,}25$

TRECHO 2,5 - 5,0:

$M_A = 1/2 (2{,}5 + 1/4 \times 2{,}5) = 1{,}5625$

$M_B = 1/2 (2{,}5 + 2/4\, 2{,}5) = 1{,}875$

$M_C = M_A$

$M_{MÁX} = M_B$

Cb TRECHO 0 - 2,5:

$$Cb = \frac{12{,}5 \times 1{,}25}{2{,}5 \times 1{,}25 + 3 \times 0{,}3125 + 4 \times 0{,}625 + 3 \times 0{,}9375} \times 1 = 1{,}6667$$

Cb TRECHO 2,5 - 5,0:

$$Cb = \frac{12{,}5 \times 1{,}875}{2{,}5 \times 1{,}875 + 3 \times 1{,}5625 + 4 \times 1{,}875 + 3 \times 1{,}5625} \times 1 = 1{,}0869$$

TRECHO 2,5 - 5,0 => MAIOR MOMENTO SOLICITANTE E MENOR FATOR Cb: PIOR CASO

(3) VERIF. FLT

$I_y = 2134,6\ cm^4 \quad r_y = 4,9251$

$I_x = 17791\ cm^4 \quad W_x = 1071,7\ cm^3 \quad Z_x = 1191,2\ cm^3$

$J = 59,733\ cm^4 \quad C_w = 532882\ cm^6 \quad \beta_1 = 0,015699\ /cm$

$$\lambda_{FLT} = L_b / r_y = 250\ cm / 4,9251\ cm = 50,760$$

$$\lambda_{PFLT} = 1,76\sqrt{\frac{20000}{25}} = 49,780$$

$$\lambda_{rFLT} = \frac{1,38\sqrt{2134,6 \times 59,73}}{4,9251 \times 59,73 \times 0,015699}\sqrt{1+\sqrt{1+\frac{27 \times 532882 \times 0,015699^2}{2134,6}}}$$

$\lambda_{rFLT} = 173,08$ VIGA INTERMEDIÁRIA

$M_{pl} = 1191,2 \times 25 = 29780\ kN.cm$

$M_r = 0,7 \times 25 \times 1071,7 = 18755\ kN.cm$

$$M_{Rd} = \frac{1,0869}{1,1}\left[297,8 - (297,8 - 187,55)\frac{(50,76 - 49,78)}{(173,08 - 49,78)}\right] = 293,39\ kN.m$$

- $M_{Rd\,lim} = 1,5 \times 1071,7 \times 25 / 1,1 = 36535\ kN.cm = 365,35\ kN.m$ OK!

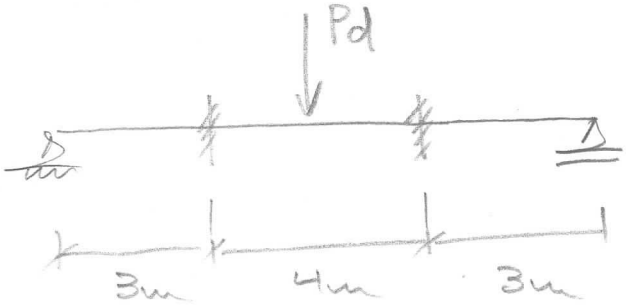
COND. LIMITE $M_{Sd} = M_{Rd}$

$M_{Sd} = P_d/2 \times 7,5/2 = 1,875\ P_d$

$1,875\ P_d = 293,39\ kN.m$

$P_d = 293,39 / 1,875 = \boxed{156,47\ kN}$

BRAMOBANA



PEDE-SE: MÁXIMA CARGA Pd DE MODO A AINDA ATENDER FLT;

$b_f = 150\,mm \quad t_f = 12,5\,mm$

$h_w = 300\,mm \quad t_w = 8\,mm$

AÇO A-36; TRAVAMENTO LAT. CONFORME INDICADO; CARGA NO MEIO DO VÃO;

① PROP. GEOM.: $I_y = 704,41\,cm^4 \quad r_y = 3,3843\,cm$

$Z_x = 765,94\,cm^3 \quad W_x = 674,47\,cm^3$

$C_w = 171975\,cm^6 \quad J = 24,651\,cm^4 \quad \beta_1 = 0,02394\,/cm$

② VERIF. FLT: $\lambda_{FLT} = \frac{L_b}{r_y} = \frac{400\,cm}{3,3843\,cm} = 118,19$

$$\lambda_{PFLT} = 1,76 \times \sqrt{\frac{20000}{25}} = 49,780$$

$$\lambda_{rFLT} = 1,38 \times \frac{\sqrt{704,41 \times 24,651}}{3,3843 \times 24,651 \times 0,02394} \sqrt{1 + \sqrt{1 + \frac{27 \times 171975 \times 0,02394^2}{704,41}}}$$

$$\lambda_{rFLT} = 162,51$$

FATOR Cb:

$$M_A = M_C = Pd/2 \times (3 + 1/4 \times 4) = 2\,Pd$$

$$M_B = M_{MÁX} = Pd/2 \times (3 + 2/4 \times 4) = 2,5\,Pd$$

$$C_b = \frac{12,5 \times 2,5\,Pd}{2,5 \times 2,5\,Pd + 3 \times 2\,Pd + 4 \times 2,5\,Pd + 3 \times 2\,Pd} = 1,1062$$

$$M_{PL} = Z_x \cdot f_y = 765,94 \times 25 = 19149\,kN.cm = 191,49\,kN.m$$

$$M_r = 0,7 f_y W_x = 0,7 \times 25 \times 674,47 = 11803\,kN.cm = 118,03\,kN.m$$

$$M_{Rd} = \frac{1,1062}{1,1}\left[191,49 - (191,49 - 118,03)\frac{(118,19 - 49,78)}{(162,51 - 49,78)}\right] = 147,74 \text{ kNm}$$

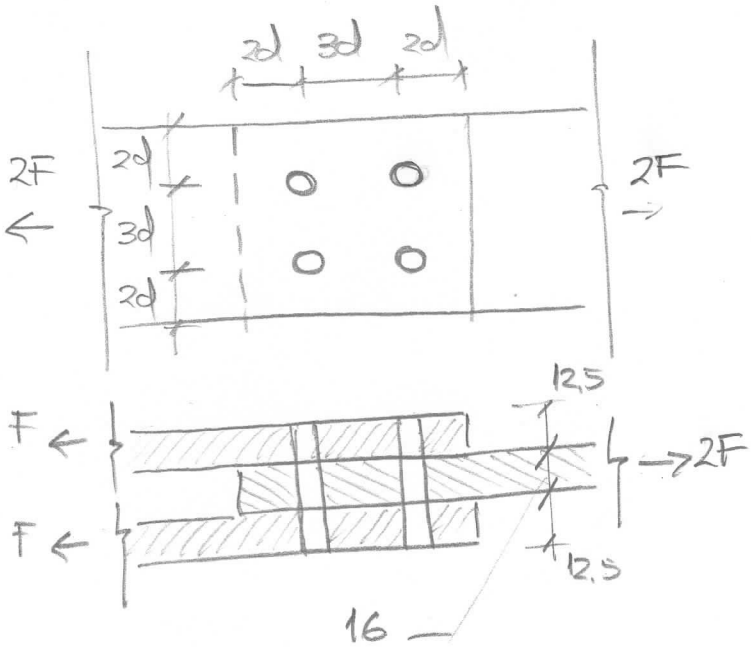
$$M_{Rd\,lim} = 1,5 \times W_x \times f_y/\gamma_{a1} = 1,5 \times 674,47 \times 25/1,1 = 229,93 \text{ kNm} \quad \text{OK!}$$

Igualando $M_{sd} = M_{Rd}$:

$$2,5 P_d = 147,74 \text{ kNm}$$

$$P_d = 147,74/2,5 = \boxed{59,096 \text{ kN}}$$

B2 AM09 AN B / NA



→ AÇO AR350;
→ FURO PADRÃO;
→ LIGAÇÃO POR ATRITO;
→ SUPERFÍCIES ATENDEM SEM PINTURA;
→ PARAFUSOS A490 $d = 5/8''$
* OVALIZAÇÃO NÃO DEVE SER PERMITIDA;

Q01) QUAL A MÁXIMA FORÇA F EM VALOR DE CÁLCULO POSSÍVEL DE SER APLICADA DE MODO QUE AS VERIFICAÇÕES DE MEIO LIGANTE SEJAM ATENDIDAS? [EM kN]

① VERIF. DE DESLIZAMENTO DE CHAPA;

F_{Tb} = 106 kN p/ A490 * VERIF ELS;

$F_{t'sk} = 0$ $\mu = 0{,}50$ $n_s = 2$ $Ch = 1{,}00$

$F_{f'Rk} = 0{,}8 \times 0{,}50 \times 1{,}00 \times 106\,kN \times 2 = 84{,}8\,kN$

$F_{fRd} = 84{,}8\,kN / 0{,}7 = 121{,}14\,kN$ p/ parafuso

p/ 4 parafusos $4 \times 121{,}14\,kN = 484{,}56\,kN = 2F$

$F = 484{,}56\,kN / 2 = \boxed{242{,}28\,kN}$ //

② VERIF. DE CORTE DOS PARAFUSOS;

$d = 5/8'' = 5/8 \times 25{,}4\,mm = 15{,}875\,mm$

$A_b = \frac{\pi}{4}(1{,}5875\,cm)^2 = 1{,}9793\,cm^2$

$F_{v'Rd} = 0{,}4 \times 1{,}9793\,cm^2 \times 103{,}5\,kN/cm^2 / 1{,}35 = 60{,}69\,kN$

$F_{VRd} = 60,69\,kN$ p/ PLANO DE CORTE

→ POR PARAFUSO $2 \times 60,69 = 121,40\,kN$

P/ 4 PARAFUSOS $4 \times 121,40\,kN = 485,6\,kN = 2F$

$F = 485,6\,kN / 2 = \boxed{242,8\,kN}$

(3) VERIFICAÇÃO DE RASGAMENTO E PRESSÃO DE APOIO;

$l_1 = 2d - (d + 1,5)/2 = 2 \times 15,875 - 0,5(15,875 + 1,5)$

$l_1 = 23,063\,mm = 2,306\,cm$

P/ CHAPA MAIS FINA:

$$F_{Rd} = MIN \begin{cases} \dfrac{1,2 \times 2,306\,cm \times 1,25\,cm \times 45\,kN/cm^2}{1,35} = 115,3\,kN \\ \dfrac{2,4 \times 1,5875\,cm \times 1,25\,cm \times 45\,kN/cm^2}{1,35} = 158,75\,kN \end{cases}$$

$F_{Rd} = 115,3\,kN$ POR FURO $\times 4 = 461,2\,kN$

$F = 461,2\,kN$

P/ CHAPA MAIS GROSSA:

$$F_{Rd} = MIN \begin{cases} \dfrac{1,2 \times 2,306\,cm \times 1,6\,cm \times 45\,kN/cm^2}{1,35} = 147,58\,kN \\ \dfrac{2,4 \times 1,5875\,cm \times 1,6\,cm \times 45\,kN/cm^2}{1,35} = 203,2\,kN \end{cases}$$

$F_{Rd} = 147,58\,kN$ POR FURO $\times 4 = 590,32\,kN$

$2F = 590,32\,kN \qquad F = \dfrac{590,32\,kN}{2} = \boxed{295,16\,kN}$

RESPOSTA 242,28 kN

* CASO A CHAPA DO MEIO TENHA ESPESSURA $t = 12,5mm$:

$$F_{cRd} = \min \begin{cases} \dfrac{1,2 \times 2,306cm \times 1,25cm \times 45kN/cm^2}{1,35} = 115,3kN \\ \dfrac{2,4 \times 1,5875cm \times 1,25cm \times 45kN/cm^2}{1,35} = 158,75kN \end{cases}$$

$F_{cRd} = 115,3kN$ P/ FURO $\times 4 = 461,2kN$

$2F = 461,2kN \qquad F = \dfrac{461,2kN}{2} = \boxed{230,6kN}$

RESPOSTA: 230,6 kN