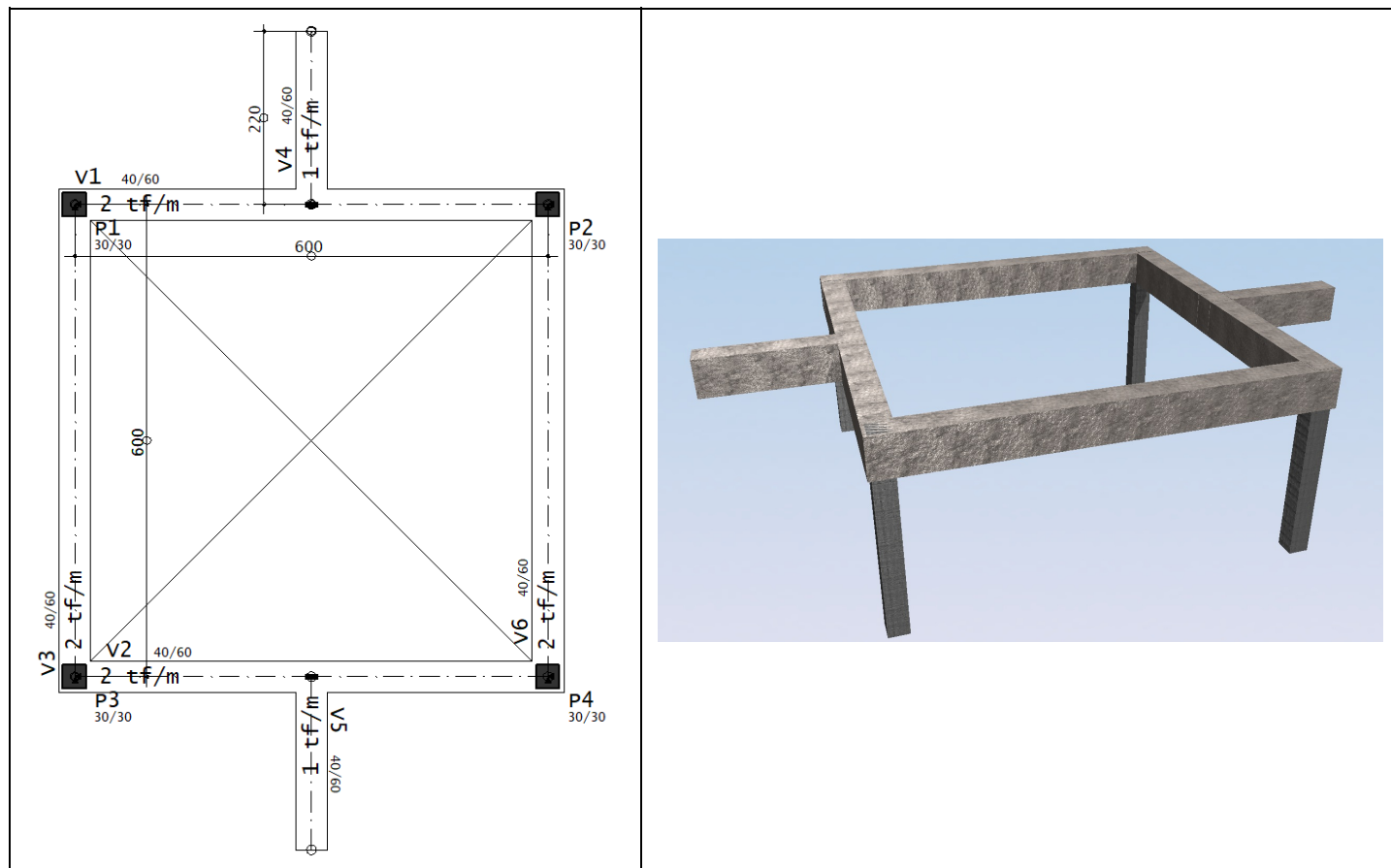


Vigas - Flexão com Torção 1

TORÇÃO

Neste exemplo, será dimensionada a armadura longitudinal e transversal de uma viga submetida a Flexão Simples combinada com torç utilizando como base a Norma Cirsoc-2005, conforme dados abaixo:

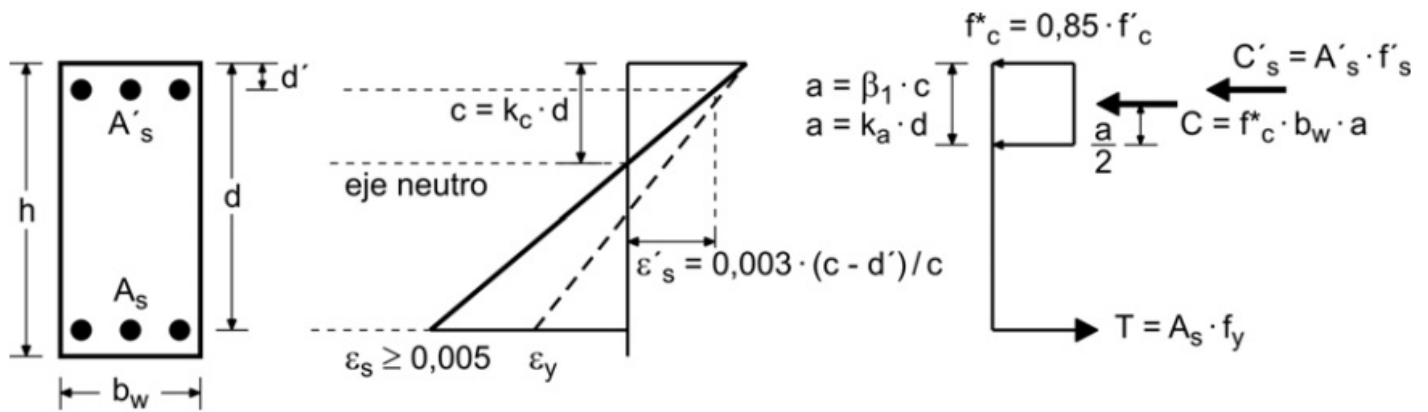


Concreto: H-25 / Aço: ADN420

bw: 40 cm / h: 60 cm

Mu:

TQS = 187 kN.m	Software B = 205,7 kN.m	Software C = 194 kN.m
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Flexão:

$$M_n = \frac{Mu}{\phi} = \frac{187,00}{0,9} = 207,78 \text{ kN.m}$$

$$d = h - C_c - d_{be} - \frac{d_b}{2} = 60 - 2 - 0,8 - 0,6 = 56,6 \text{ cm}$$

$$m_n = \frac{M_n}{0,85 \cdot f'_c \cdot b_w \cdot d^2} = \frac{207,78}{0,85 \cdot 25000 \cdot 0,40 \cdot 0,566^2} = 0,0763$$

$$k_a = 1 - (1 - 2 \cdot m_n)^{\frac{1}{2}} = 1 - (1 - 2 \cdot 0,0763)^{\frac{1}{2}} = 0,0795$$

$$x = \frac{k_a \cdot d}{0,85} = 5,29 \text{ cm}$$

$$A_s = \frac{k_a \cdot f_c^* \cdot b_w \cdot d}{f_y} = \frac{0,0795 \cdot 21,25 \cdot 40 \cdot 56,6}{420} = 9,10 \text{ cm}^2$$

$$A_s \geq A_{s,min}$$

$$A_{s1,min} = \frac{0,25 \cdot \sqrt{f'_c}}{f_y} \cdot b_w \cdot d = \frac{0,25 \cdot \sqrt{25}}{420} \cdot 40 \cdot 56,6 = 6,75 \text{ cm}^2$$

$$A_{s2,min} = \frac{1,4 \cdot b_w \cdot d}{f_y} = \frac{1,4 \cdot 40 \cdot 56,6}{420} = 7,55 \text{ cm}^2$$

$$A_{s,req} = A_s \cdot 1,33 = 12,14 \text{ cm}^2$$

TQS = 9,10 cm ²	Software B = 9,15 cm ²	Software C = 9,12 cm ²
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$$9,10 \text{ cm}^2 \geq 9,10 \text{ cm}^2 \rightarrow \text{OK!!}$$

$$\phi M_n (187,00 \text{ KN.m}) \approx Mu (187,00 \text{ KN.m}) \rightarrow \text{OK!!}$$

Cortante:

TQS	Software B	Software C
$V_u = 13,08 \text{ t}$	$V_u = 12,84 \text{ t}$	$V_u = 13,32 \text{ t}$
$V_{u,design} = 13,08 \text{ t}$	$V_{u,design} = 10,77 \text{ t}$	$V_{u,design} = 10,70 \text{ t}$

$$\beta_w = \frac{A_s}{b_w \cdot d} V_n = V_c + V_s \quad V_u = 13,08 \text{ t} \quad V_{u,design} = 13,08 \text{ t}$$

$$V_c = \left(1 + \frac{N_u}{14 \cdot A_g}\right) \sqrt{f'_c} \cdot \frac{1}{6} \cdot b_w \cdot d = \left(1 + \frac{0}{14 \cdot 0,12}\right) \sqrt{25} \cdot \frac{1}{6} \cdot 4 \cdot 5,66 = 18,87 \text{ t}$$

$$V_{c,lim} = 0,3 \cdot \sqrt{f'_c} \cdot b_w \cdot d \cdot \sqrt{1 + \frac{0,3 \cdot N_u}{A_g}} = 33,96 \text{ t}$$

$$V_c \leq V_{c,lim} \quad \text{OK!!}$$

$$V_n = \frac{V_{u,design}}{\phi_{0,75}} = V_c + V_s \rightarrow V_s = 0 \text{ t} \rightarrow V_n = 17,44 \text{ t}$$

$$V_{s,lim} = \frac{2}{3} \cdot \sqrt{f'_c} \cdot b_w \cdot d = V_{s,lim} = \frac{2}{3} \cdot \sqrt{f'_c} \cdot b_w \cdot d = 75,47 \text{ t}$$

$$\phi_{0,75} \rightarrow \phi V_n \geq V_u \rightarrow 13,08 \geq 13,08 \rightarrow \text{OK!!}$$

Torção:

T_u :

TQS = 2,72 tf.m	Software B = 2,71 tf.m	Software C = 2,69 tf.m
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Recobrimento até eixo do estribo (rec_e): 2,4 cm

$$A_{cp} = b_w \cdot h = 0,4 \cdot 0,6 = 0,24 \text{ m}^2$$

$$p_{cp} = 2 \cdot (b_w + h) = 2 \cdot (0,4 + 0,6) = 2 \text{ m}$$

$$A_{oh} = (b_w - (2 \cdot rec_e)) \cdot (h - (2 \cdot rec_e)) = (0,4 - 0,048) \cdot (0,6 - 0,048) = 0,20 \text{ m}^2$$

$$p_h = (2 \cdot (b_w - (2 \cdot rec_e))) + (2 \cdot (h - (2 \cdot rec_e))) = (2 \cdot (0,352)) + (2 \cdot (0,552)) = 1,84 \text{ m}$$

$$T_u \leq \frac{1}{12} \cdot \phi \cdot \sqrt{f'_c} \cdot \frac{A_{cp}^2}{p_{cp}} = \frac{1}{12} \cdot 0,75 \cdot \sqrt{25} \cdot \frac{0,24^2}{2} = 9 \text{ kN.m} \leq 27,2 \text{ kN.m} \rightarrow \text{Precisa considerar!}$$

Fissuração:

$$\sqrt{\left(\frac{V_u}{b_w \cdot d}\right)^2 + \left(\frac{T_u \cdot p_h}{1,7 \cdot A_{oh}}\right)^2} \leq \phi \cdot \left(\frac{V_c}{b_w \cdot d} + \frac{2}{3} \cdot \sqrt{f'_c}\right)$$

$$\sqrt{\left(\frac{130,8}{0,4 \cdot 0,566}\right)^2 + \left(\frac{27,2 \cdot 1,81}{1,7 \cdot 0,20^2}\right)^2} \leq 0,75 \cdot \left(\frac{188,7}{0,4 \cdot 0,6} + \frac{2}{3} \cdot \sqrt{25}\right)$$

$$959,62 \text{ kN/m}^2 \leq 3089,69 \text{ kN/m}^2 \rightarrow \text{OK!!}$$

Armaduras Transversal:

$$\frac{A_l}{p_h} = \frac{A_t}{s} = \frac{T_n}{\left(1,7 \cdot A_{oh} \cdot f_{yt} \cdot \cot g(\theta)\right)} = \frac{\frac{27,2}{0,75}}{\left(1,7 \cdot 0,20 \cdot 420000 \cdot \cot g(45)\right)} = 2,54 \text{ cm}^2/\text{m}$$

$$A_l = 2,54 \cdot 1,84 = 4,67 \text{ cm}^2$$

$$A_{l,min} = \frac{5}{12} \cdot \sqrt{f'_c} \cdot \frac{A_{cp}}{f_{yl}} - \left(\frac{A_t}{s}\right) \cdot p_h \cdot \frac{f_{yt}}{f_{yl}} = 0,4167 \cdot 5 \cdot 5,71 - (2,54 \cdot 1,84) = 7,23 \text{ cm}^2$$

$$A_{l,min} \geq A_l \rightarrow A_{l,min} \text{ OK!!}$$

Considerando 2 ramos:

$$0,5 \cdot \frac{A_v}{s} + \frac{A_t}{s} = 0,25 \cdot \frac{0}{100} + 2,54 = 2,54 \text{ cm}^2/\text{m} - 1R$$

$$A_{v,min} = \frac{1}{16} \cdot \sqrt{f'_c} \cdot \frac{b_w \cdot s}{f_{yt}} \geq 0,33 \cdot \frac{b_w \cdot s}{f_{yt}} = 3,14 \text{ cm}^2/\text{m} - 2R$$

$$A_v \geq A_{v,min} \rightarrow 5,08 (2R) \geq 3,14 (2R) \rightarrow \text{OK!!}$$

Espaçamento:

$$s \leq s_{max} \rightarrow s_{max} = \text{menor valor entre } s_1 \text{ e } s_2$$

$$s_1 = \frac{p_h}{8} = 23 \text{ cm ou } s_2 = 300 \text{ mm}$$

$$s_1 = \frac{d}{2} = 28,3 \text{ cm ou } s_2 = 400 \text{ mm}$$

$$\phi_t = 8 \text{ mm} \rightarrow A_v = 5,56 \text{ cm}^2/\text{m} \rightarrow \phi 8 \text{ c/ } 18 \text{ cm}$$

$$\phi_t = 8 \text{ mm} \rightarrow A_v = 5,56 \text{ cm}^2/\text{m} \rightarrow \phi 8 \text{ c/ } 18 \text{ cm}$$

$$\phi V_n (23,98 \text{ t}) \geq V_u (13,08 \text{ t}) \rightarrow \text{OK!!}$$

Armadura Longitudinal:

$$d_{b,min} \geq \frac{s}{24} \text{ ou } 10 \text{ mm} \rightarrow 10 \text{ mm!!}$$

$$\text{Inferior: } \frac{A_l}{2} + A_{sl} = \frac{7,23}{2} + 9,10 = 12,71 \text{ cm}^2 \rightarrow 7\phi 16 \text{ mm } (14,07 \text{ cm}^2)$$

$$\text{Superior: } \frac{A_l}{2} - A_{sl} = \frac{7,23}{2} = 3,62 \text{ cm}^2 \rightarrow 5\emptyset 10 \text{ mm (3,93 cm}^2\text{)}$$

$$\text{Laterais: } \frac{A_l}{2} = \frac{7,23}{2} = 3,62 \text{ cm}^2 \rightarrow 5\emptyset 10 \text{ mm (3,93 cm}^2\text{)}$$