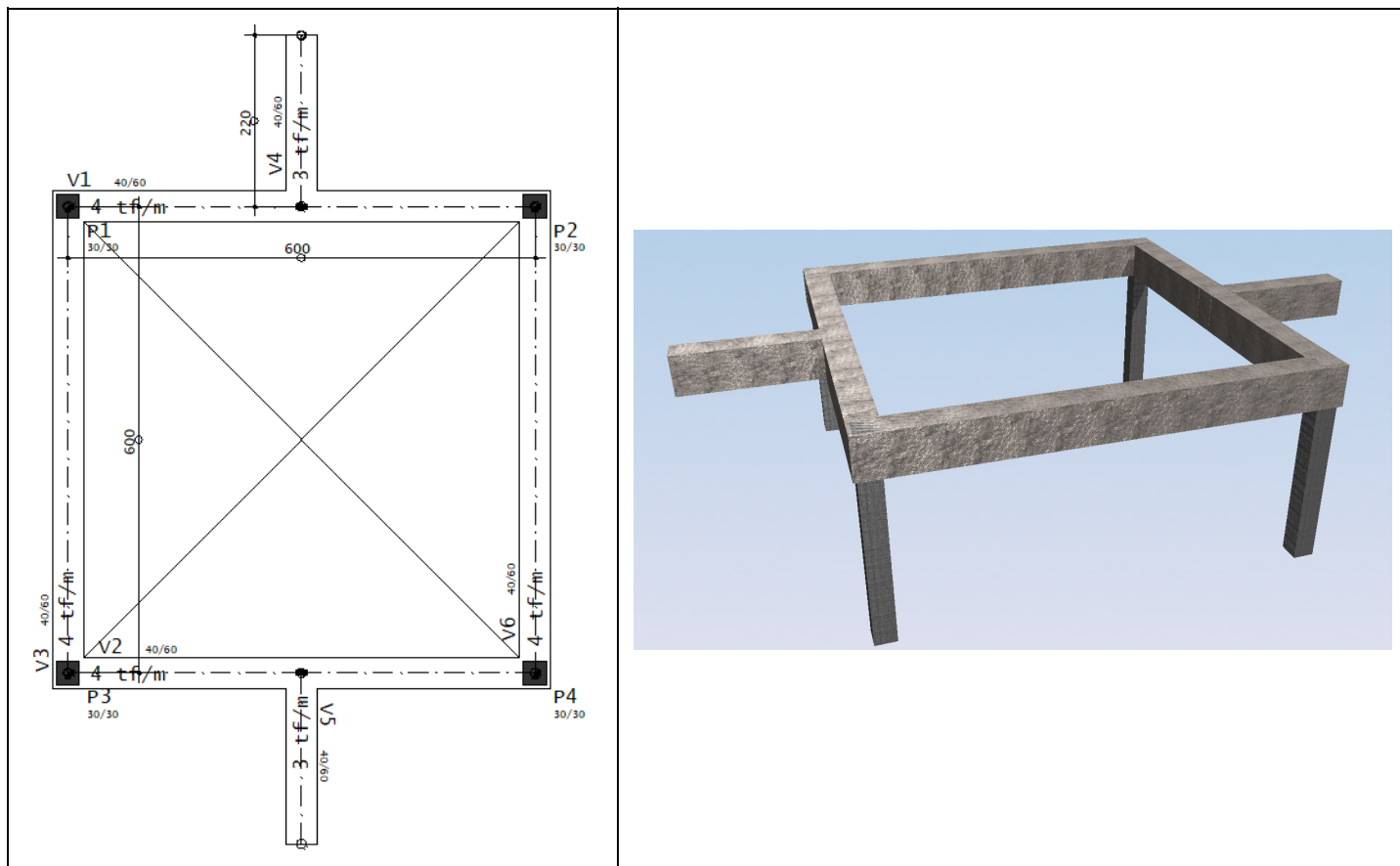


Vigas - Flexão com Torção 3

TORÇÃO

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

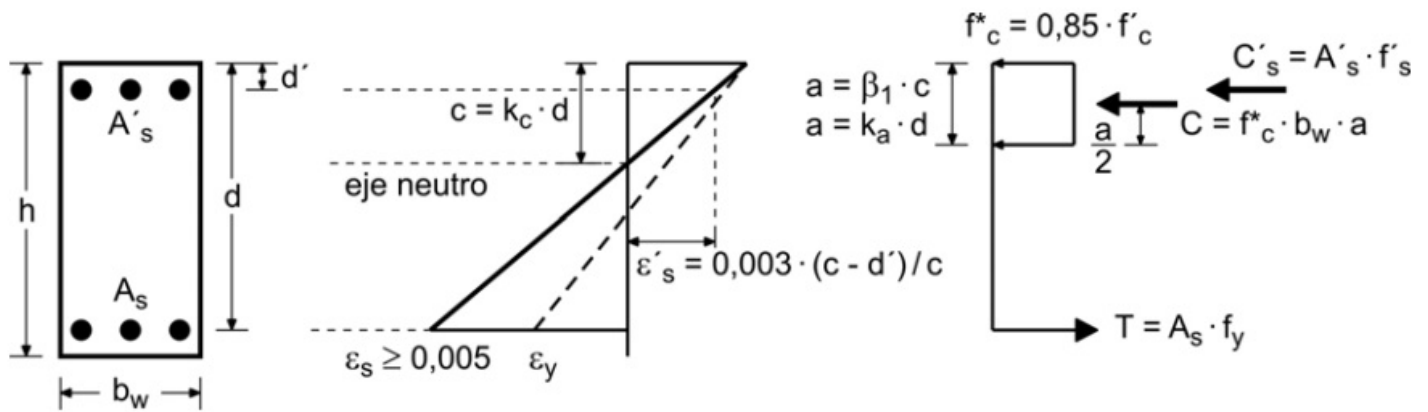


Concreto: H-25 / Aço: ADN420

bw: 40 cm / h: 60 cm

Mu:

TQS = 360 kN.m	Software B = 394,48 kN.m	Software C = 367,55 kN.m
----------------	--------------------------	--------------------------



Flexão:

$$M_n = \frac{Mu}{\phi} = \frac{360}{0,9} = 400 \text{ kN.m}$$

$$d = h - C_c - d_{be} - \frac{d_b}{2} = 60 - 2 - 1 - 1 = 56,0 \text{ cm}$$

$$m_n = \frac{M_n}{0,85 \cdot f'_c \cdot b_w \cdot d^2} = \frac{400}{0,85 \cdot 25000 \cdot 0,40 \cdot 0,56^2} = 0,1501$$

$$k_a = 1 - (1 - 2 \cdot m_n)^{\frac{1}{2}} = 1 - (1 - 2 \cdot 0,1501)^{\frac{1}{2}} = 0,1634$$

$$x = \frac{k_a \cdot d}{0,85} = 10,77 \text{ cm}$$

$$A_s = \frac{k_a \cdot f'_c \cdot b_w \cdot d}{f_y} = \frac{0,1634 \cdot 21,25 \cdot 40 \cdot 56,0}{420} = 18,52 \text{ cm}^2$$

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

$$A_{s1,min} = \frac{0,25 \cdot \sqrt{f'_c}}{f_y} \cdot b_w \cdot d = \frac{0,25 \cdot \sqrt{25}}{420} \cdot 40 \cdot 56 = 6,67 \text{ cm}^2$$

$$A_{s2,min} = \frac{1,4 \cdot b_w \cdot d}{f_y} = \frac{1,4 \cdot 40 \cdot 56}{420} = 7,47 \text{ cm}^2$$

$$A_{s,req} = A_s \cdot 1,33 = 24,69 \text{ cm}^2$$

TQS = 18,52 cm ²	Software B = 18,09 cm ²	Software C = 18,74 cm ²
-----------------------------	------------------------------------	------------------------------------

18,52 cm² ≥ 18,52 cm² → OK!!

ØMn (360 KN.m) ≥ Mu (360,00 KN.m) → OK!!

Cortante:

TQS	Software B	Software C
Vu = 23,93 t	Vu = 23,84 t	Vu = 23,90 t

$V_{u,design} = 23,93 \text{ t}$	$V_{u,design} = 20,19 \text{ t}$	$V_{u,design} = 20,22 \text{ t}$
----------------------------------	----------------------------------	----------------------------------

$$\beta_w = \frac{A_s}{b_w \cdot d} V_n = V_c + V_s \quad V_u = 23,93 \text{ t} \quad V_{u,design} = 23,93 \text{ t}$$

$$V_c = \left(1 + \frac{N_u}{14 \cdot A_g}\right) \sqrt{f'_c} \cdot \frac{1}{6} \cdot b_w \cdot d = \left(1 + \frac{0}{14 \cdot 0,12}\right) \sqrt{25} \cdot \frac{1}{6} \cdot 4 \cdot 5,6 = 18,67 \text{ t}$$

$$V_{c,lim} = 0,3 \cdot \sqrt{f'_c} \cdot b_w \cdot d \cdot \sqrt{1 + \frac{0,3 \cdot N_u}{A_g}} = 33,60 \text{ t}$$

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

$$V_n = \frac{V_{u,design}}{\phi_{0,75}} = V_c + V_s \rightarrow V_s = 13,31 \text{ t} \rightarrow V_n = 31,91 \text{ t}$$

$$V_{s,lim} = \frac{2}{3} \cdot \sqrt{f'_c} \cdot b_w \cdot d = 74,67 \text{ t}$$

$$A_v = \frac{V_s \cdot s}{f_{yt} \cdot d} = \frac{13,31 \cdot 100}{4,2 \cdot 55,8} = 5,68 \text{ cm}^2/\text{m}$$

$$\phi_{0,75} \rightarrow \phi V_n \geq V_u \rightarrow 23,93 \geq 23,93 \rightarrow OK!!$$

Torção:

T_u :

$TQS = 6,10 \text{ tf.m}$	$\text{Software B} = 6,04 \text{ tf.m}$	$\text{Software C} = 6,08 \text{ tf.m}$
---------------------------	---	---

Recobrimento até eixo do estribo (rec_e): 2,4 cm

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

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

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

$$p_h = (2 \cdot (b_w - (2 \cdot rec_e))) + (2 \cdot (h - (2 \cdot rec_e))) = 1,81 \text{ m}$$

$$T_u \leq \frac{1}{12} \cdot \phi \cdot \sqrt{f'_c} \cdot \frac{A_{cp}^2}{p_{cp}} = \frac{1}{12} \cdot 0,75 \cdot \sqrt{25} \cdot \frac{0,24^2}{2} = 9 \text{ kN.m} \leq 61,0 \text{ kN.m} \rightarrow \text{Precisa considerar!}$$

Fissuração:

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

$$\sqrt{\left(\frac{239,3}{0,4 \cdot 0,558}\right)^2 + \left(\frac{61 \cdot 1,80}{1,7 \cdot 0,20^2}\right)^2} \leq 0,75 \cdot \left(\frac{186}{0,4 \cdot 0,558} + \frac{2}{3} \cdot \sqrt{25}\right)$$

$$1987,94 \text{ kN.m}^2 \leq 3083,33,00 \text{ kN.m}^2 \rightarrow OK!!$$

Armaduras Transversal:

$$\frac{A_l}{p_h} = \frac{A_t}{s} = \frac{T_n}{(1,7 \cdot A_{oh} \cdot f_{yt} \cdot \cot g(\theta))} = \frac{\frac{61}{0,75}}{(1,7 \cdot 0,20 \cdot 420000 \cdot \cot g(45))} = 5,86 \text{ cm}^2/\text{m}$$

$$A_l = 5,86 \cdot 1,80 = 10,60 \text{ cm}^2$$

$$A_{l,min} = \frac{5}{12} \cdot \sqrt{f'_c} \cdot \frac{A_{cp}}{f_{yl}} - \left(\frac{A_t}{s}\right) \cdot p_h \cdot \frac{f_{yt}}{f_{yl}} = 0,4167 \cdot 5 \cdot 5,71 - (5,86 \cdot 1,81) = 1,30 \text{ cm}^2$$

Considerando 2 ramos pela largura:

$$0,5 \cdot \frac{A_v}{s} + \frac{A_t}{s} = 0,5 \cdot \frac{5,68}{1} + 5,86 = 8,70 \text{ cm}^2/\text{m} - 1R$$

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

$$A_v \geq A_{v,min} \rightarrow 17,40 (2R) \geq 3,14 (2R) \rightarrow OK!!$$

Espaçamento:

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

$$s_1 = \frac{p_h}{8} = 22,5 \text{ cm ou } s_2 = 300 \text{ mm}$$

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

$$\phi_t = 10 \text{ mm} \rightarrow A_v = 17,55 \text{ cm}^2/\text{m} - \phi 10 \text{ c/ } 9 \text{ cm}$$

$$\phi_t = 10 \text{ mm} \rightarrow A_v = 17,55 \text{ cm}^2/\text{m} \rightarrow \phi 10 \text{ c/ } 9 \text{ cm}$$

$$\phi V_n (44,96 \text{ t}) \geq V_u (23,93 \text{ t}) \rightarrow OK!!$$

Armadura Longitudinal:

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

$$\text{Inferior: } \frac{A_l}{2} + A_{sl} = \frac{10,60}{2} + 18,52 = 23,82 \text{ cm}^2 \rightarrow 8\phi 20 \text{ mm } (25,14 \text{ cm}^2)$$

$$\text{Superior: } \frac{A_l}{2} - A_{sl} = \frac{10,60}{2} = 5,30 \text{ cm}^2 \rightarrow 7\phi 10 \text{ mm } (5,50 \text{ cm}^2)$$

$$\text{Laterais: } \frac{A_l}{2} = \frac{10,60}{2} = 5,30 \text{ cm}^2 \rightarrow 7\phi 10 \text{ mm } (5,50 \text{ cm}^2)$$