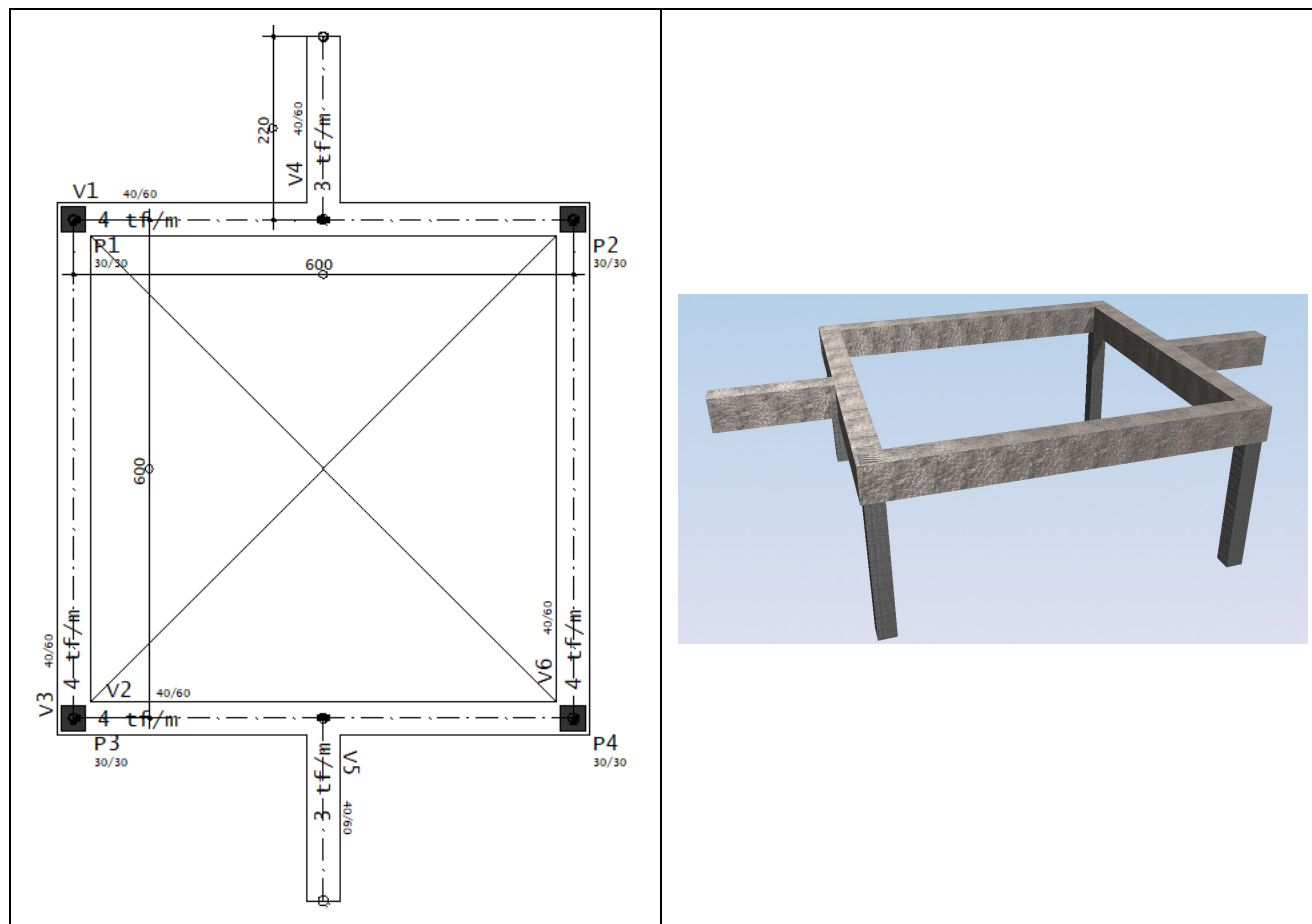


Vigas - Flexão com Torção 3

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 ACI 318-19, conforme dados abaixo:

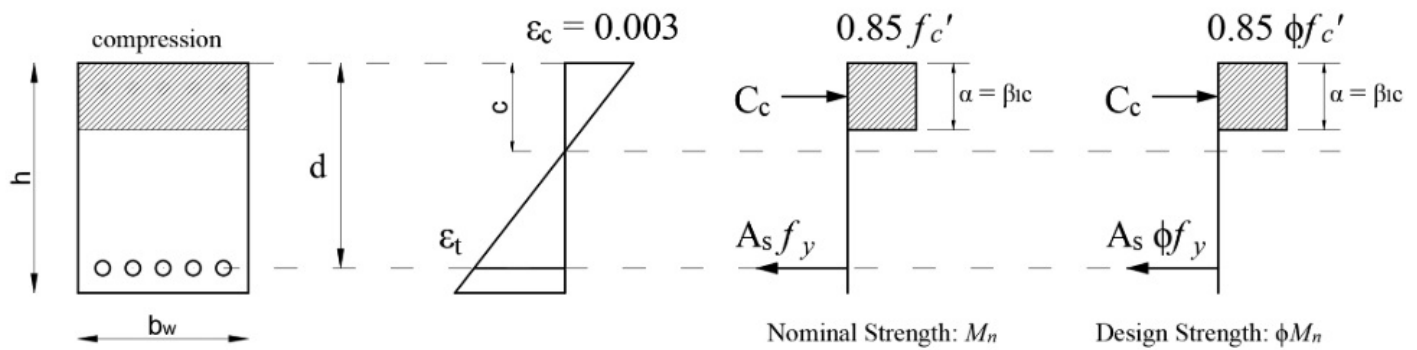


Concreto - C25 (4000 psi) / Aço – ADN420 (60 ksi)

bw: 15,75 in / h: 23,62 in

Mu:

TQS = 3186 kip.in	Software B = 3491,15 kip.in	Software C = 3252,82 kip.in
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Flexão:

$$M_n = \frac{M_u}{\phi} = \frac{3186}{0,9} = \mathbf{3540 \text{ kip.in}}$$

$$d = h - C_c - d_{be} - \frac{d_b}{2} = 23,62 - 1,57 - 0,5 - 0,437 = \mathbf{21,11 \text{ in}}$$

$$R_n = \frac{M_{n,req}}{b_w \cdot d^2} = \frac{3540}{8 \cdot 21,11^2} = 0,504 \text{ ksi} = 504,25 \text{ psi}$$

$$\rho = \left(0,85 \cdot \frac{f'_c}{f_y}\right) \cdot \left[1 - \sqrt{1 - \left(\frac{2 \cdot R_n}{0,85 \cdot f'_c}\right)}\right] = \left(0,85 \cdot \frac{4}{60}\right) \cdot \left(1 - \sqrt{1 - \left(\frac{2 \cdot 0,504}{0,85 \cdot 4}\right)}\right) = \mathbf{0,0091}$$

$$A_s = \rho \cdot b_w \cdot d = 0,0091 \cdot 15,75 \cdot 21,11 = \mathbf{3,04 \text{ in}^2}$$

$A_{s,min}$ (ACI 318-19 – 9.6.1.2)

$$\left(\frac{3 \cdot \sqrt{f'_c}}{f_y}\right) \cdot b_w \cdot d = \left(\frac{3 \cdot \sqrt{4000}}{60000}\right) \cdot 15,75 \cdot 21,11 = \mathbf{1,05 \text{ in}^2}$$

$$\left(\frac{200}{f_y}\right) \cdot b_w \cdot d = \left(\frac{200}{60000}\right) \cdot 15,75 \cdot 21,11 = \mathbf{1,11 \text{ in}^2}$$

$$A_{s,min} = \mathbf{1,11 \text{ in}^2}$$

TQS = 3,04 in ²	Software B = 1,42 in ²	Software C = 1,47 in ²
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3,04 in² ≥ 3,04 in² → OK!

φMn (3186 kip.in) ≥ Mu (3186 kip.in) → OK!!

Verificação do fator de redução (ACI318-19 – 21.2.2)

$$\alpha = \frac{A_s \cdot f_y}{0,85 \cdot f'_c \cdot b_w} = \frac{3,04 \cdot 60}{0,85 \cdot 4 \cdot 15,75} = \mathbf{3,41 \text{ in}}$$

$$\text{Linha Neutra: } c = \frac{\alpha}{\beta_1} = \frac{3,41}{0,85} = 4,01 \text{ in}$$

$$\varepsilon_t = 0,003 \cdot \left(\frac{d - c}{c} \right) = 0,003 \cdot \left(\frac{21,11 - 4,01}{4,01} \right) = 0,013$$

0,013 ≥ 0,005 → OK! Tension Controlled! → ø 0,90 OK!

Cortante:

TQS	Software B	Software C
Vu = 52,76 kips	Vu = 52,57 kips	Vu = 52,70 kips
Vu,design = 52,76 kips	Vu,design = 44,52 kips	Vu,design = 44,59 kips

$$V_n = V_c + V_s$$

$$V_u = 52,76 \text{ kips}$$

$$V_{u,design} = 52,76 \text{ kips}$$

$$V_c = 2 \cdot \lambda \cdot \sqrt{f'_c} \cdot b_w \cdot d = 2 \cdot 1 \cdot \sqrt{4000} \cdot 15,75 \cdot 21,11 = 42,06 \text{ kips}$$

$$V_n = \frac{V_{u,design}}{\phi_{0,75}} = V_c + V_s \rightarrow V_s = 28,29 \text{ kips} \rightarrow V_n = 70,35 \text{ kips}$$

$$V_{s,lim} = 8 \cdot \sqrt{f'_c} \cdot b_w \cdot d = 8 \cdot \sqrt{4000} \cdot 15,75 \cdot 21,11 = 168,24 \text{ kips}$$

$$A_v = \frac{V_s \cdot s}{f_{yt} \cdot d} = \frac{A_v}{s} = \frac{28,29}{60 \cdot 21,11} = 0,022 \text{ in}^2/\text{in}$$

ø0,75 → øVn ≥ Vu → 49,37 ≥ 49,37 → OK!!

Torção:

Tu:

TQS = 539,85 kip.in	Software B = 534,54 kip.in	Software C = 538,08 kip.in
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$$\text{Recobrimento até eixo do estribo (rec}_e\text{): } 1,82 \text{ in}$$

$$A_{cp} = b_w \cdot h = 15,75 \cdot 23,62 = 372,02 \text{ in}^2$$

$$p_{cp} = 2 \cdot (b_w + h) = 2 \cdot (15,75 + 23,62) = 78,74 \text{ in}$$

$$A_{oh} = (b_w - (2 \cdot rec_e)) \cdot (h - (2 \cdot rec_e)) = (15,75 - 3,52) \cdot (23,62 - 3,52) = 245,82 \text{ in}^2$$

$$p_h = (2 \cdot (b_w - (2 \cdot rec_e))) + (2 \cdot (h - (2 \cdot rec_e))) = (2 \cdot (12,23)) + (2 \cdot (20,10)) = 64,66 \text{ in}$$

$$T_u \leq \lambda \cdot \phi \cdot \sqrt{f'_c} \cdot \frac{A_{cp}^2}{p_{cp}} = 1 \cdot 0,75 \cdot \sqrt{4000} \cdot \frac{372,02^2}{78,74} = 79,65 \text{ kip.in} \leq 539,85 \text{ kip.in} \rightarrow \text{Precisa considerar!}$$

Fissuração:

$$\sqrt{\left(\frac{V_u}{b_w \cdot d}\right)^2 + \left(\frac{T_u \cdot p_h}{1,7 \cdot A_{oh}}\right)^2} \leq \phi \cdot \left(\frac{V_c}{b_w \cdot d} + 0,66 \cdot \sqrt{f'_c}\right)$$

$$\sqrt{\left(\frac{49,37}{15,75 \cdot 21,36}\right)^2 + \left(\frac{389,40 \cdot 64,66}{1,7 \cdot 245,82^2}\right)^2} \leq 0,75 \cdot \left(\frac{42,19}{15,75 \cdot 21,36} + 0,66 \cdot \sqrt{25}\right)$$

$$0,38 \text{ kip/in}^2 \leq 0,457 \text{ kip/in}^2 \rightarrow OK!!$$

Armaduras Transversal:

$$\frac{A_l}{p_h} = \frac{A_t}{s} = \frac{T_n}{(1,7 \cdot A_{oh} \cdot f_{yt} \cdot \cot g(\theta))} = \frac{\frac{539,85}{0,75}}{(1,7 \cdot 245,82 \cdot 60 \cdot \cot g(45))} = 0,029 \text{ in}^2/\text{in}$$

$$A_l = 0,029 \cdot 64,66 = 1,87 \text{ in}^2$$

$$A_{l,min} = 5 \cdot \sqrt{f'_c} \cdot \frac{A_{cp}}{f_{yl}} - \left(\frac{A_t}{s}\right) \cdot p_h \cdot \frac{f_{yt}}{f_{yl}} = 5 \cdot \frac{63,24}{1000} \cdot 6,20 - (1,87) = 0,09 \text{ in}^2$$

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

Considerando 2 ramos:

$$0,5 \cdot \frac{A_v}{s} + \frac{A_t}{s} = 0,25 \cdot \frac{0,022}{1} + 0,029 = 0,04 \text{ in}^2/\text{in} - 1R$$

$$A_{v,min} = 0,75 \cdot \sqrt{f'_c} \cdot \frac{b_w \cdot s}{f_{yt}} \geq 50 \cdot \frac{b_w}{f_{yt}} = 0,013 \text{ in}^2/\text{in} - 2R$$

$$A_v \geq A_{v,min} \rightarrow 0,080 (2R) \geq 0,013 (2R) \rightarrow OK!!$$

Espaçamento:

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

$$s_1 = \frac{p_h}{8} = 9 \text{ in ou } s_2 = 11,81 \text{ in}$$

$$s_1 = \frac{d}{2} = 10,56 \text{ in ou } s_2 = 15,75 \text{ in}$$

$$\phi_t = \#4 \rightarrow A_v = 0,080 \text{ in}^2/\text{in} \rightarrow \#4 @ 5 \text{ in}$$

$$\phi_t = \#4 \rightarrow A_v = 0,080 \text{ in}^2/\text{in} \rightarrow \#4 @ 5 \text{ in}$$

$$\phi V_n (107,55 \text{ t}) \geq V_u (52,76 \text{ t}) \rightarrow \text{OK!!}$$

Armadura Longitudinal:

$$d_{b,min} \geq 0,042 \cdot s, \#3$$

$$\text{Inferior: } \frac{A_l}{2} + A_{sl} = \frac{1,87}{2} + 3,04 = 3,98 \text{ in}^2 \rightarrow 7\#7 (4,20 \text{ in}^2)$$

$$\text{Superior: } \frac{A_l}{2} - A_{sl} = \frac{1,87}{2} = 0,94 \text{ in}^2 \rightarrow 5\#4 (1,00 \text{ in}^2)$$

$$\text{Laterais: } \frac{A_l}{2} = \frac{1,87}{2} = 0,94 \text{ in}^2 \rightarrow 5\#4 (1,00 \text{ in}^2)$$