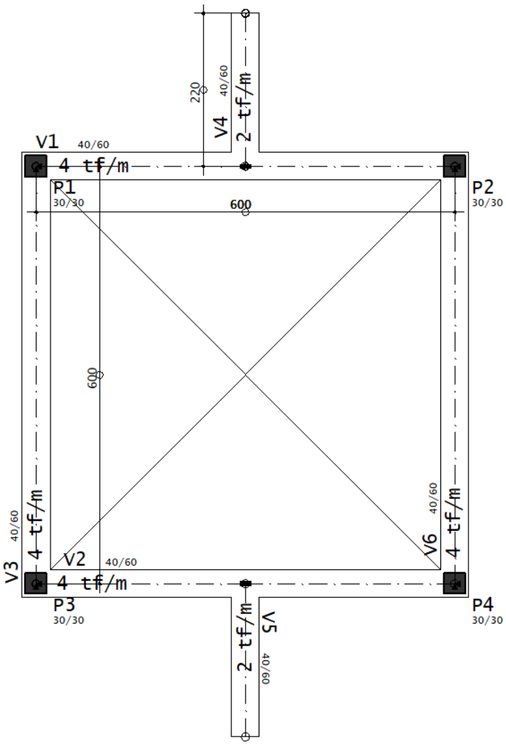
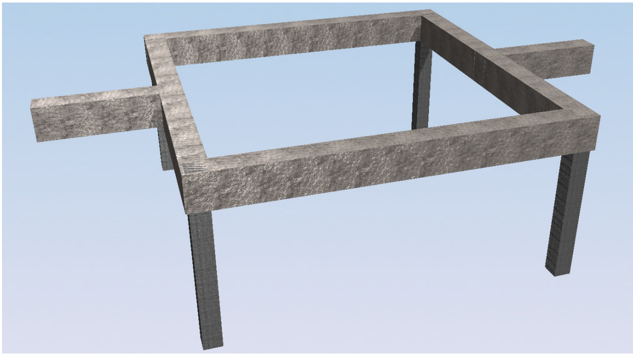
Vigas - Flexão com Torção 2

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:



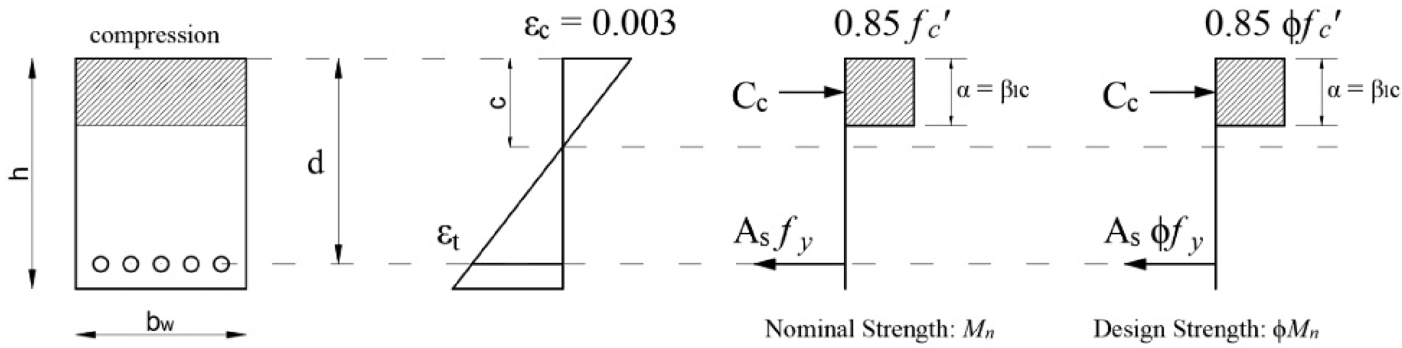


Concreto - C25 (4000 psi) / Aço – ADN420 (60 ksi)

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

Mu:

TQS = 2849,70 kip.in	**Software B = 3127,06 kip.in**	**Software C = 2910,77 kip.in**



Flexão:

$$M_n = \frac{Mu}{\emptyset} = \frac{2849{,}70}{0{,}9} = \mathbf{3166{,}33\ kip.in}$$

$$d = h - C_c - d_{be} - \frac{d_b}{2} = 23{,}62 - 1{,}57 - 0{,}5 - 0{,}375 = \mathbf{21{,}18\ in}$$

$$R_n = \frac{M_{n,req}}{b_w \cdot d^2} = \frac{3166{,}33}{8 \cdot 21{,}18^2} = 0{,}448\ ksi = 448{,}36\ \mathbf{psi}$$

$$\rho = \left(0{,}85 \cdot \frac{f'_c}{f_y}\right) \cdot [1 - \sqrt{1 - \left(\frac{2 \cdot R_n}{0{,}85 \cdot f'_c}\right)} = (0{,}85 \cdot \frac{4}{60}) \cdot (1 - \sqrt{1 - (\frac{2 \cdot 0{,}448}{0{,}85 \cdot 4}})) = \mathbf{0{,}0080}$$

$$\boldsymbol{A_s} = \rho \cdot b_w \cdot d = 0{,}0080 \cdot 15{,}75 \cdot 21{,}18 = \mathbf{2{,}68\ in^2}$$

As,min (ACI 318-19 – 9.6.1.2)

$$\left(\frac{3 \cdot \sqrt{f'_c}}{f_y}\right) \cdot b_w \cdot d = \left(\frac{3 \cdot \sqrt{4000}}{60000}\right) \cdot 15{,}75 \cdot 21{,}18 = \mathbf{1{,}05\ in^2}$$

$$\left(\frac{200}{f_y}\right) \cdot b_w \cdot d = \left(\frac{200}{60000}\right) \cdot 15{,}75 \cdot 21{,}18 = \mathbf{1{,}11\ in^2}$$

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

TQS = 2,68 in²	**Software B = 1,42 in²**	**Software C = 1,47 in²**

2,68 in² ≥ 2,68 in² → OK!
øMn (2849,70 kip.in) ≥ Mu (2849,70 kip.in) → OK!!

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

$$\alpha = \frac{A_s \cdot f_y}{0{,}85 \cdot f'_c \cdot b_w} = \frac{2{,}68 \cdot 60}{0{,}85 \cdot 4 \cdot 15{,}75} = 3{,}01\ in$$

$$Linha\ Neutra:\ \boldsymbol{c} = \frac{\boldsymbol{\alpha}}{\boldsymbol{\beta_1}} = \frac{3{,}01}{\mathbf{0{,}85}} = 3{,}54\ \mathbf{in}$$

$$\varepsilon_t = 0{,}003 \cdot \left(\frac{d - c}{c}\right) = 0{,}003 \cdot \left(\frac{21{,}18 - 3{,}54}{3{,}54}\right) = \mathbf{0{,}015}$$

0,015 ≥ 0,005 → OK! Tension Controlled! → ø 0,90 OK!

Cortante:

TQS	Software B	Software C
Vu = 49,37 kips	Vu = 49,17 kips	Vu = 49,33 kips
Vu,design = 49,37 kips	Vu,design = 41,12 kips	Vu,design = 41,26 kips

$$V_n = V_c + V_s$$

$$\boldsymbol{V_u = 49,37\ kips}$$

$$\boldsymbol{V_{u,design} = 49,37\ kips}$$

$$V_c = 2 \cdot \lambda \cdot \sqrt{f'_c} \cdot b_w \cdot d = 2 \cdot 1 \cdot \sqrt{4000} \cdot 15{,}75 \cdot 21{,}18 = 42{,}19\ \boldsymbol{kips}$$

$$\boldsymbol{V_n = \frac{V_{u,design}}{\emptyset_{0,75}} = V_c + V_s \quad \rightarrow \quad V_s = 23,64\ kips \quad \rightarrow \quad V_n = 65,83\ kips}$$

$$V_{s,lim} = 8 \cdot \sqrt{f'_c} \cdot b_w \cdot d = 8 \cdot \sqrt{4000} \cdot 15{,}75 \cdot 21{,}18 = \boldsymbol{168,74\ kips}$$

$$A_v = \frac{V_s \cdot s}{f_{yt} \cdot d} = \frac{A_v}{s} = \frac{23{,}64}{60 \cdot 21{,}18} = 0{,}018\ in^2/in$$

Ø0,75 → øVn ≥ Vu → 49,37 ≥ 49,37 → OK!!

Torção:

Tu:

TQS = 389,40 kip.in	Software B = 384,09 kip.in	Software C = 387,63 kip.in

$$Recobrimento\ até\ eixo\ do\ estribo\ (rec_e): 1{,}82\ in$$

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

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

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

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

$$T_u \leq 0{,}083 \cdot \emptyset \cdot \sqrt{f'_c} \cdot \frac{A_{cp}{}^2}{p_{cp}} = 0{,}083 \cdot 0{,}75 \cdot \sqrt{25} \cdot \frac{372{,}02^2}{78{,}74} = 79{,}65\ kip.in \leq 389{,}40\ \text{kip.in}$$
$$\rightarrow\ Precisa\ considerar!$$

Fissuração:

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

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

$$0{,}30\ kip/in^2 \ \leq 0{,}457\ kip/in^2 \rightarrow OK!!$$

Armaduras Transversal:

$$\frac{A_l}{p_h} = \frac{A_t}{s} = \frac{T_n}{\left(1{,}7 \cdot A_{oh} \cdot f_{yt} \cdot cotg(\theta)\right)} = \frac{\frac{389{,}40}{0{,}75}}{\left(1{,}7 \cdot 245{,}82 \cdot 60 \cdot cotg(45)\right)} = 0{,}021\ in^2/in$$

$$A_l = 0{,}021 \cdot 64{,}66 = 1{,}35\ in^2$$

$$A_{l,min} = 0{,}42 \cdot \sqrt{f'_c} \cdot \frac{A_{cp}}{f_{yl}} - \left(\frac{A_t}{s}\right) \cdot p_h \cdot \frac{f_{yt}}{f_{yl}} = 0{,}42 \cdot 0{,}73 \cdot 6{,}20 - (1{,}35) = 0{,}55\ in^2$$

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

Considerando 2 ramos:

$$0{,}5 \cdot \frac{A_v}{s} + \frac{A_t}{s} = 0{,}25 \cdot \frac{0{,}018}{1} + 0{,}021 = 0{,}03\ in^2/in \ - 1R$$

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

$$\boldsymbol{A_v \geq A_{v,min}} \rightarrow \mathbf{0,06\ (2}\boldsymbol{R}\mathbf{)} \geq \mathbf{0,013\ (2}\boldsymbol{R}\mathbf{)} \rightarrow \boldsymbol{OK}!!$$

Espaçamento:

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

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

$$\boldsymbol{s_1} = \frac{d}{\mathbf{2}} = \mathbf{10,59}\ \boldsymbol{in\ \ ou\ \ s_2} = \mathbf{15,75}\ \boldsymbol{in}$$

$$\emptyset_t = \#4 \ \rightarrow \boldsymbol{A_v} = \mathbf{0,067}\ \boldsymbol{in^2/in} \rightarrow \ \#\mathbf{4}\ @\ \mathbf{6}\ \boldsymbol{in}$$

Øt = #4 → Av = 0,067 in²/in → #4 @ 6 in

øVn (95,20 t) ≥ Vu (49,37 t) → OK!!

Armadura Longitudinal:

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

$$Inferior: \frac{A_l}{2} + A_{sl} = \frac{1{,}35}{2} + 2{,}68 = 3{,}36\ in^2 \rightarrow 8\#6\ (3{,}52\ in^2)$$

$$Superior: \frac{A_l}{2} - A_{sl} = \frac{1{,}35}{2} = 0{,}68\ in^2 \rightarrow 4\#4\ (0{,}80\ in^2)$$

$$Laterais: \frac{A_l}{2} = \frac{1{,}35}{2} = 0{,}68\ in^2 \rightarrow 4\#4\ (0{,}80\ in^2)$$