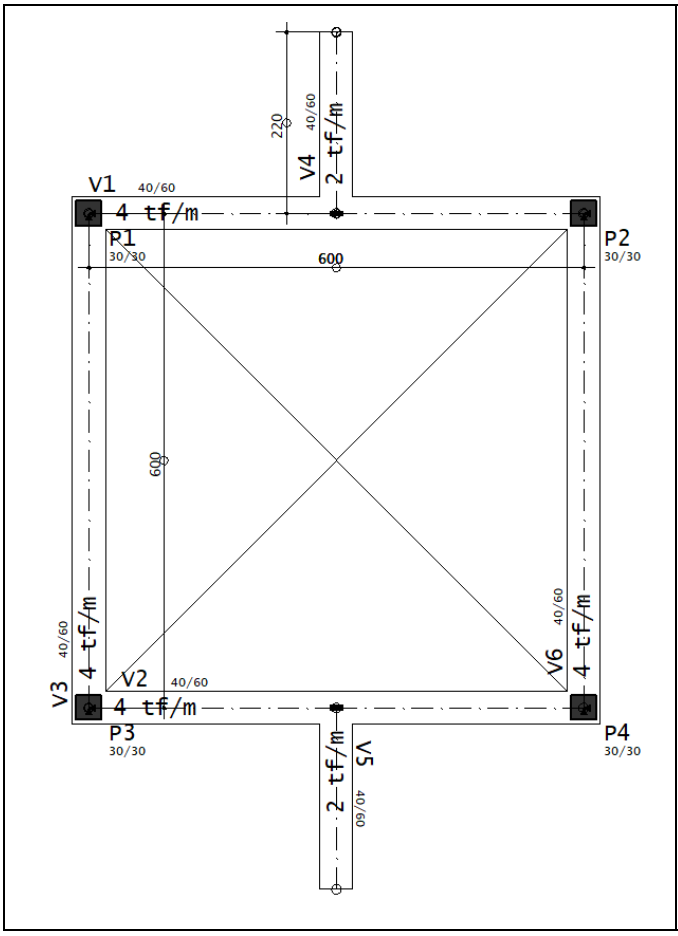
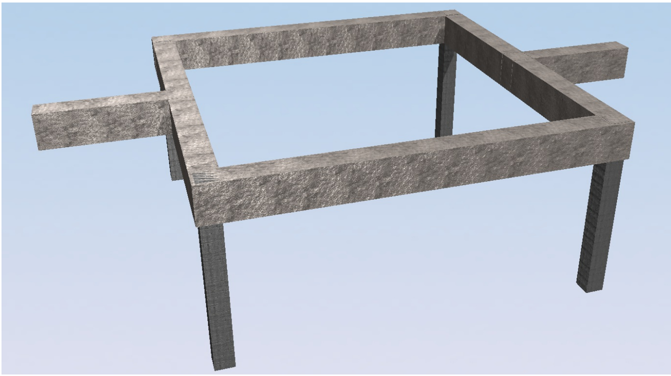
Vigas - Flexão com Torção 2

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 Cirsoc-2005, conforme dados abaixo:



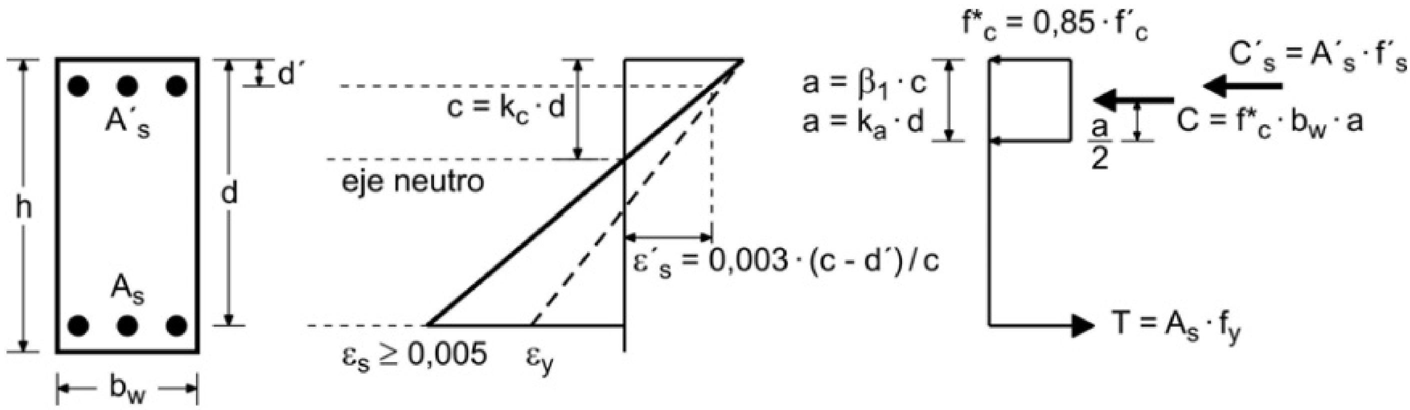


Concreto: H-25 / Aço: ADN420

bw: 40 cm / h: 60 cm

Mu:

TQS = 322 kN.m	**Software B = 353,34 kN.m**	**Software C = 328,9 kN.m**



Flexão:

$$M_n = \frac{Mu}{\emptyset} = \frac{322}{0{,}9} = \mathbf{357,78\ kN.m}$$

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

$$m_n = \frac{M_n}{0{,}85\ \cdot f'_c\ \cdot b_w\ \cdot\ d^2} = \frac{357{,}78}{0{,}85\ \cdot 25000\ \cdot 0{,}40\ \cdot\ 0{,}56^2} = \mathbf{0,1342}$$

$$k_a = 1 - \ (1 - 2\ \cdot\ m_n)^{\frac{1}{2}} = 1 - \ (1 - 2\ \cdot 0{,}1342)^{\frac{1}{2}} = \mathbf{0,1447}$$

$$\boldsymbol{x} = \frac{\boldsymbol{k_a \cdot d}}{\mathbf{0{,}85}} = \mathbf{9,53\ cm}$$

$$\boldsymbol{A_s} = \frac{k_a\ \cdot\ f*_c \cdot\ b_w\ \cdot d}{f_y} = \frac{0{,}1447\ \cdot 21{,}25\ \cdot 40\ \cdot 56}{420} = \mathbf{16,40\ cm^2}$$

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

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

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

$$A_{s,req} = \ A_s\ \cdot 1{,}33 = 21{,}86\ cm^2$$

TQS = 16,40 cm²	**Software B = 16,36 cm²**	**Software C = 16,41 cm²**

16,40 cm² ≥ 16,40 cm² → OK!!
øMn (322,00 KN.m) ≥ Mu (322,00 KN.m) → OK!!

Cortante:

TQS	Software B	Software C
Vu = 22,39 t	**Vu = 22,30 t**	**Vu = 22,37 t**

Vu,design = 22,39 t	**Vu,design = 18,65 t**	**Vu,design = 18,71 t**

$$V_n = V_c + V_s$$

$$\boldsymbol{V_u = 22,39\ t}$$

$$\boldsymbol{V_{u,design} = 22,39\ t}$$

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

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

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

$$\boldsymbol{V_n = \frac{V_{u,design}}{\emptyset_{0,75}} = V_c + V_s \ \ \rightarrow \ \ V_s = 11,18\ t \ \ \rightarrow \ \ V_n = 29,85\ t}$$

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

$$A_v = \frac{V_s \cdot s}{f_{yt} \cdot d} = \frac{11,18 \cdot 100}{4,2 \cdot 56} = 4,75\ cm^2/m$$

Ø0,75 → øVn ≥ Vu → 22,39 ≥ 22,39 → OK!!

Torção:

Tu:

TQS = 4,40 tf.m	**Software B = 4,34 tf.m**	**Software C = 4,38 tf.m**

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

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

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

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

$$p_h = (2 \cdot \left(b_w - (2 \cdot rec_e)\right) + (2 \cdot \left(h - (2 \cdot rec_e)\right) = \left(2 \cdot (0,352)\right) + \left(2 \cdot (0,552)\right) = 1,81\ m$$

$$T_u \leq \frac{1}{12} \cdot \emptyset \cdot \sqrt{f'_c} \cdot \frac{{A_{cp}}^2}{p_{cp}} = \frac{1}{12} \cdot 0,75 \cdot \sqrt{25} \cdot \frac{0,24^2}{2} = 9\ kN.m \leq 44,0\ \mathrm{kN.m} \ \ \rightarrow \ \ Precisa\ considerar!$$

Fissuração:

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

$$\sqrt{\left(\frac{223{,}9}{0{,}4\cdot 0{,}56}\right)^2+\left(\frac{44\cdot 1{,}81}{1{,}7\cdot 0{,}20^2}\right)^2}\leq 0{,}75\cdot\left(\frac{186{,}7}{0{,}4\cdot 0{,}56}+\frac{2}{3}\cdot\sqrt{25}\right)$$

$$1592{,}30\ kN.m^2\ \leq 3083{,}33\ kN.m^2 \rightarrow OK!!$$

Armaduras Transversal:

$$\frac{A_l}{p_h}=\frac{A_t}{s}=\frac{T_n}{\left(1{,}7\cdot A_{oh}\cdot f_{yt}\cdot cotg(\theta)\right)}=\frac{\frac{44}{0{,}75}}{\left(1{,}7\cdot 0{,}20\cdot 420000\cdot cotg(45)\right)}=4{,}23\ cm^2/m$$

$$A_l=4{,}11\cdot 1{,}81=7{,}65\ cm^2$$

$$A_{l,min}=\frac{5}{12}\cdot\sqrt{f'_c}\cdot\frac{A_{cp}}{f_{yl}}-\left(\frac{A_t}{s}\right)\cdot p_h\cdot\frac{f_{yt}}{f_{yl}}=0{,}4167\cdot 5\cdot 5{,}71-(4{,}11\cdot 1{,}84)=4{,}26\ cm^2$$

Considerando 2 ramos pela largura:

$$0{,}5\cdot\frac{A_v}{s}+\frac{A_t}{s}=0{,}5\cdot\frac{4{,}75}{1}+4{,}27=\ 6{,}65\ cm^2/m\ \ -1R$$

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

$$\boldsymbol{A_v\geq A_{v,min}\rightarrow 13{,}30\ (2R)\geq 3{,}14\ (2R)\rightarrow OK!!}$$

Espaçamento:

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

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

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

$$\emptyset_t=10\ mm\ \rightarrow\ \boldsymbol{A_v=14{,}36\ cm^2/m\ -\ \emptyset 10\ c/\ 11\ cm}$$

Øt = 10 mm → Av = 14,36 cm²/m → ø10 c/ 11 cm

øVn (39,75 t) ≥ Vu (22,39 t) → OK!!

Armadura Longitudinal:

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

$$Inferior:\ \frac{A_l}{2}+A_{sl}=\frac{7{,}65}{2}+16{,}40=20{,}23\ cm^2\rightarrow 7\emptyset 20\ mm\ (21{,}99\ cm^2)$$

$$Superior:\ \frac{A_l}{2}-A_{sl}=\frac{7{,}40}{2}=3{,}70\ cm^2\ \rightarrow 5\emptyset 10\ mm\ (3{,}93\ cm^2)$$

$$Laterais: \frac{A_l}{2} = \frac{7{,}23}{2} = 3{,}70\ cm^2 \rightarrow 5\text{Ø}10\ mm\ (3{,}93\ cm^2)$$