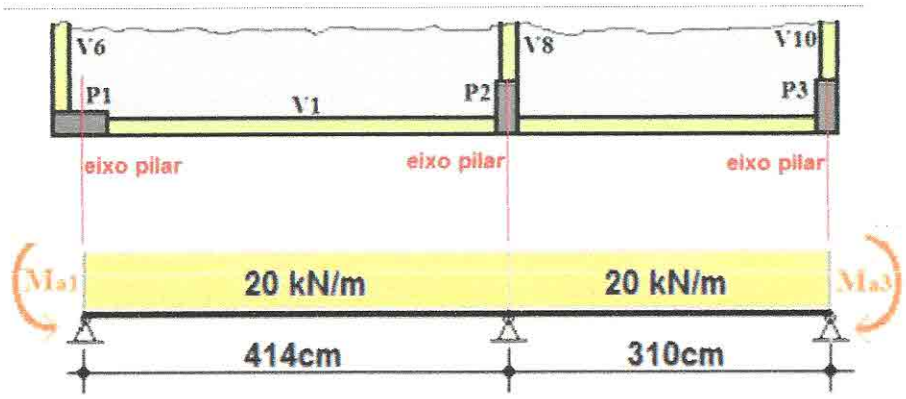
CONCRETO ARMADO I

Viga V1

i) Esquema estático:



ii) Momento de semi-engastamento Ma1:

$$\bullet\ r_{v1,a} = \frac{I_{v1}}{L_{v1}} = \frac{\frac{b.h^3}{12}}{L_{v1}} = \frac{\frac{14.40^3}{12}}{414} = 180{,}35cm^3 \qquad \bullet\ r_{i1} = r_{s1} = \frac{I_{p1}}{L_{p1}} = \frac{\frac{b.h^3}{12}}{L_{p1}} = \frac{\frac{20.40^3}{12}}{300} = 355{,}56cm^3$$

$$\bullet\ M_{eng1} = \frac{p.L_v^2}{12} = \frac{20.4{,}14^2}{12} = 28{,}57kN.m$$

$$\bullet\ M_{a1} = M_{eng1} \cdot \frac{r_i + r_s}{r_i + r_s + r_v} = 28{,}57 \cdot \frac{355{,}56 + 355{,}56}{355{,}56 + 355{,}56 + 180{,}35} = 22{,}79kN.m$$

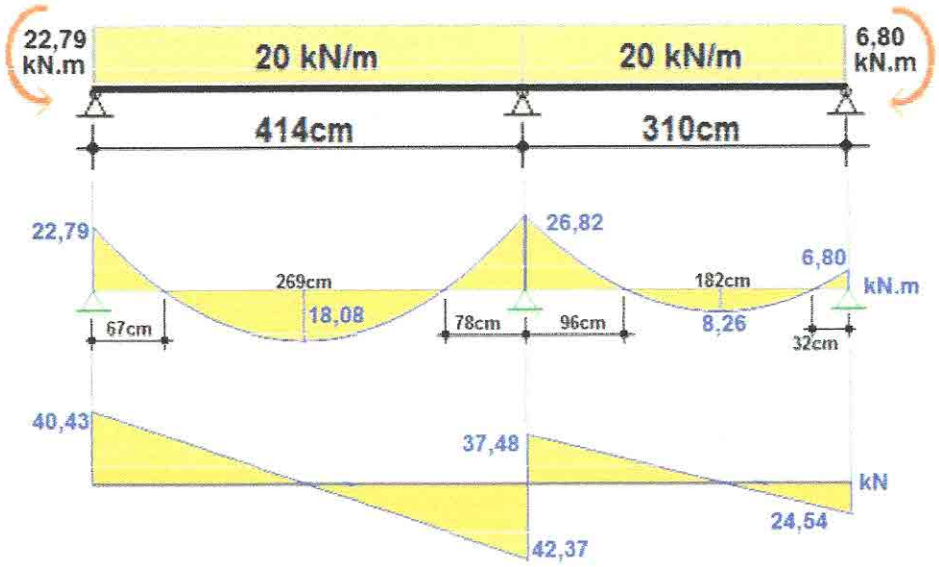
ii) Momento de semi-engastamento Ma3:

$$\bullet\ r_{v1,b} = \frac{I_v}{L_v} = \frac{\frac{b.h^3}{12}}{L_v} = \frac{\frac{14.40^3}{12}}{310} = 240{,}86cm^3 \qquad \bullet\ r_3 = r_{s3} = \frac{I_{p2}}{L_{p2}} = \frac{\frac{b.h^3}{12}}{L_{p2}} = \frac{\frac{40.20^3}{12}}{300} = 88{,}89cm^3$$

$$\bullet\ M_{eng3} = \frac{p.L_v^2}{12} = \frac{20.3{,}10^2}{12} = 16{,}02kN.m$$

$$\bullet\ M_{a3} = M_{eng3} \cdot \frac{r_i + r_s}{r_i + r_s + r_v} = 16{,}02 \cdot \frac{88{,}89 + 88{,}89}{88{,}89 + 88{,}89 + 240{,}86} = 6{,}80kN.m$$

iii) Diagramas:



iv) Valor de As^+: M_k=18,08kN.m

- $M_{dlim} = \mu_{lim}.b.d^2.f_{cd} = 0,32.14.35^2.\frac{2,5}{1,4} = 98,0kN.m > 1,4.18,08 \rightarrow$ Armadura simples

- $y = d.\left(1 - \sqrt{1 - \frac{M_d}{0,425.b.d^2.f_{cd}}}\right) = 35.\left(1 - \sqrt{1 - \frac{1,4.18,08.100}{0,425.14.35^2.2,5/1,4}}\right) = 3,59cm$

- $As = \frac{0,85.f_{cd}.b.y}{f_{yd}} = \frac{0,85.2,5/1,4.14.3,59}{50/1,15} = 1,75cm^2$ $\rightarrow$ As > As min. $\rightarrow$ *OK*

- $As_{min} = \frac{\omega_{min}.Ac.f_{cd}}{f_{yd}} = \frac{0,035.(14.40).2,5/1,4}{50/1,15} = 0,81cm^2$

iv) Valor de As^+: M_k=8,26kN.m

- $M_{dlim} = \mu_{lim}.b.d^2.f_{cd} = 0,32.14.35^2.\frac{2,5}{1,4} = 98,0kN.m > 1,4.8,26 \rightarrow$ Armadura simples

- $y = d.\left(1 - \sqrt{1 - \frac{Md}{0,425.b.d^2.f_{cd}}}\right) = 35.\left(1 - \sqrt{1 - \frac{1,4.8,26.100}{0,425.14.35^2.2,5/1,4}}\right) = 1,59cm$

- $As = \frac{0,85.f_{cd}.b.y}{f_{yd}} = \frac{0,85.2,5/1,4.14.1,59}{50/1,15} = 0,78cm^2$ → As < As min.

- $A_{smin} = \frac{\omega_{min}.A_c.f_{cd}}{f_{yd}} = \frac{0,035(14.40).2,5/1,4}{50/1,15} = 0,81cm^2$ → As = As min. = $0,81cm^2$

iv) Valor de As^-: M_k=26,82kN.m

- $M_{dlim} = \mu_{lim}.b.d^2.f_{cd} = 0,32.14.35^2.\frac{2,5}{1,4} = 98,0kN.m > 1,4.26,82 \rightarrow$ Armadura simples

- $y = d.\left(1 - \sqrt{1 - \frac{Md}{0,425.b.d^2.f_{cd}}}\right) = 35.\left(1 - \sqrt{1 - \frac{1,4.26,82.100}{0,425.14.35^2.2,5/1,4}}\right) = 5,48cm$

- $As = \frac{0,85.f_{cd}.b.y}{f_{yd}} = \frac{0,85.2,5/1,4.14.5,48}{50/1,15} = 2,68cm^2$ → As > As min. → *OK*

- $A_{smin} = \frac{\omega_{min}.A_c.f_{cd}}{f_{yd}} = \frac{0,035(14.40).2,5/1,4}{50/1,15} = 0,81cm^2$

iv) Valor de As^-: M_k=22,79kN.m

- $M_{dlim} = \mu_{lim}.b.d^2.f_{cd} = 0,32.14.35^2.\frac{2,5}{1,4} = 98,0kN.m > 1,4.22,79 \rightarrow$ Armadura simples

- $y = d.\left(1 - \sqrt{1 - \frac{Md}{0,425.b.d^2.f_{cd}}}\right) = 35.\left(1 - \sqrt{1 - \frac{1,4.22,79.100}{0,425.14.35^2.2,5/1,4}}\right) = 4,59cm$

- $As = \frac{0,85.f_{cd}.b.y}{f_{yd}} = \frac{0,85.2,5/1,4.14.4,59}{50/1,15} = 2,24cm^2$ → As > As min. → *OK*

- $A_{smin} = \frac{\omega_{min}.A_c.f_{cd}}{f_{yd}} = \frac{0,035(14.40).2,5/1,4}{50/1,15} = 0,81cm^2$

v) Armadura de projeto e verificações:

- $As^- = 0,81cm^2 \rightarrow A_{proj} = 2\phi 8,0\ (1,00cm^2)$

- $e_h >$ { - 20mm=2,0cm; - diâmetro da barra, feixe, ou luva=0,8cm; - 1,2.dmax = 1,2.19mm=2,28cm; - vibrador = 4cm (arm. negativa) } $\rightarrow$ $e_h \geq 4,0cm$

- $e_h = 14 - 2.Cobr - 2.\phi t - 2.1,25 = 4,5cm$ $\Rightarrow$ 4,5cm > 4,0cm $\rightarrow$ *OK*

- $d'_r = Cobr + \phi t + \frac{0,8}{2} = 3,90cm$ $\rightarrow$ 3,9cm < 5,0cm $\rightarrow$ *OK*

- $a = 0$ $\rightarrow$ $0 < 5\%.h = 2,0cm$ $\rightarrow$ *OK* (Rcc $\leftrightarrow$ CG)

v) Armadura de projeto e verificações:

- $As^- = 2,68cm^2 \rightarrow A_{proj} =$ { - $2\phi 16,0\ (4,0cm^2)$; - $4\phi 10,0\ (3,2cm^2)$ } $\rightarrow$ $A_{proj} = 2\phi 12,5$

- $e_h >$ { - 20mm=2,0cm; - diâmetro da barra, feixe, ou luva=1,25cm; - 1,2.dmax = 1,2.19mm=2,28cm; - vibrador = 4cm (arm. negativa) } $\rightarrow$ $e_h \geq 4,0cm$

- $e_h = 14 - 2.Cobr - 2.\phi t - 2.1,25 = 4,5cm$ $\Rightarrow$ 4,5cm > 4,0cm $\rightarrow$ *OK*

- $d'_r = Cobr + \phi t + \frac{1,25}{2} = 4,13cm$ $\rightarrow$ 4,13cm < 5,0cm $\rightarrow$ *OK*

- $a = 0$ $\rightarrow$ $0 < 5\%.h = 2,0cm$ $\rightarrow$ *OK* (Rcc $\leftrightarrow$ CG)

v) Armadura de projeto e verificações:

- $As^{-} = 2,24cm^2 \rightarrow A_{proj} = \begin{cases} - 2\phi 12,5\ (2,5cm^2) \\ - 4\phi 10,0\ (3,2cm^2) \end{cases} \rightarrow A_{proj} = 2\phi 12,5$

- $e_h > \begin{cases} - 20mm=2,0cm \\ - \text{diâmetro da barra, feixe, ou luva}=1,25cm \\ - 1,2.dmax = 1,2.19mm=2,28cm \\ - \text{vibrador} = 4cm\ (\text{arm. negativa}) \end{cases} \rightarrow e_h \geq 4,0cm$

- $e_h = 14 - 2.Cobr - 2.\phi t - 2.1,25 = 4,5cm \Rightarrow 4,5cm > 4,0cm \rightarrow OK$

- $d'_r = Cobr + \phi t + \frac{1,25}{2} = 4,13cm \rightarrow 4,13cm < 5,0cm \rightarrow OK$

- $a = 0 \rightarrow 0 < 5\%.h = 2,0cm \rightarrow OK$ (Rcc ↔ CG)

vi) Armadura apoios externos:

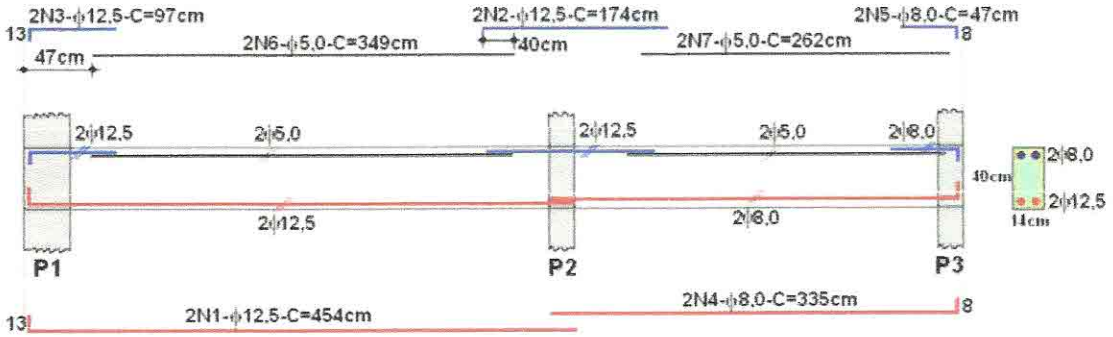
- $A_{sa,\ esquerdo} > \begin{cases} - 2\phi \\ - |M_{apoio}| > \frac{M_{vão}}{2} \rightarrow \frac{A_{svão}}{4} \rightarrow \frac{2,24}{4} = 0,56cm^2 \\ - \frac{\cancel{al.V_d}}{\cancel{d.f_{yd}}} \rightarrow \text{Não (momento} \neq 0) \end{cases} \Rightarrow A_{apoio} = 2\phi 12,5$

(Em P1)

- $A_{sa,\ direito} > \begin{cases} - 2\phi \\ - |M_{apoio}| > \frac{M_{vão}}{2} \rightarrow \frac{A_{svão}}{4} \rightarrow \frac{0,81}{4} = 0,20cm^2 \\ - \frac{\cancel{al.V_d}}{\cancel{d.f_{yd}}} \rightarrow \text{Não (momento} \neq 0) \end{cases} \Rightarrow A_{apoio} = 2\phi 8,0$

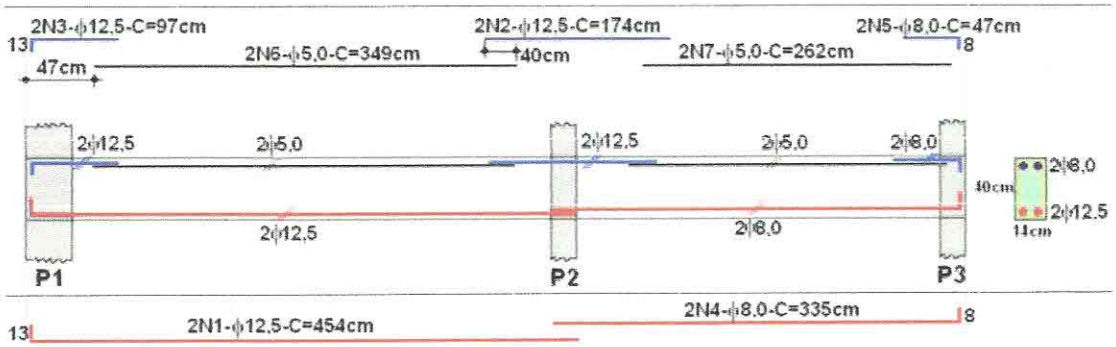
(Em P3)

vii) Detalhamento:



- $N_1 = 414 + \frac{40}{2} - 3 + 13 + \frac{20}{2} = 454cm$
- $N_3 = 67 + \frac{40}{2} - 3 + 13 = 97cm$
- $N_2 = 78 + 96 = 174cm$
- $N_4 = 310 + \frac{20}{2} - 3 + 8 + \frac{20}{2} = 335cm$

vii) Detalhamento:



- $N_5 = 32 + \frac{20}{2} - 3 + 8 = 47cm$
- $N_7 = 182 + 2.40 = 262cm$
- $N_6 = 269 + 2.40 = 349cm$

iv) Valor de As^-: M_k=6,80kN.m

- $M_{dlim} = \mu_{lim}.b.d^2.f_{cd} = 0,32.14.35^2.\frac{2,5}{1,4} = 98,0kN.m > 1,4.6,80 \rightarrow$ Armadura simples

- $y = d.\left(1 - \sqrt{1 - \frac{Md}{0,425.b.d^2.f_{cd}}}\right) = 35.\left(1 - \sqrt{1 - \frac{1,4.6,80.100}{0,425.14.35^2.2,5/1,4}}\right) = 1,30cm$

- $As = \frac{0,85.f_{cd}.b.y}{f_{yd}} = \frac{0,85.2,5/1,4.14.1,30}{50/1,15} = 0,64cm^2 \rightarrow As < As\,min.$

- $As_{min} = \frac{\omega_{min}.A_c.f_{cd}}{f_{yd}} = \frac{0,035(14.40).2,5/1,4}{50/1,15} = 0,81cm^2$

$\downarrow$

$As = As\,min. = 0,81cm^2$

v) Armadura de projeto e verificações:

- $As^+ = 1,75cm^2 \rightarrow A_{proj} = 2\phi 12,5\ (2,50cm^2)$

- $e_h >$
  - 20mm=2,0cm
  - diâmetro da **barra**, feixe, ou luva=1,25cm
  - 1,2.dmax = 1,2.19mm=2,28cm

  $\rightarrow e_h \geq 2,28cm$

- $e_h = 14 - 2.Cobr - 2.\phi t - 2.1,25 = 4,5cm \Rightarrow 4,5cm > 2,28cm \rightarrow OK$

- $d'_r = Cobr + \phi t + \frac{1,25}{2} = 4,13cm \rightarrow 4,13cm < 5,0cm \rightarrow OK$

- $a = 0 \rightarrow 0 < 5\%.h = 2,0cm \rightarrow OK$ (Rcc $\leftrightarrow$ CG)

v) Armadura de projeto e verificações:

- As^+ e $As^- = 0,81cm^2 \rightarrow A_{proj} = 2\phi 8,0\ (1,00cm^2)$

- $e_h >$
  - 20mm=2,0cm
  - diâmetro da barra, feixe, ou luva=0,8cm
  - 1,2.dmax = 1,2.19mm=2,28cm
  - vibrador = 4cm (arm. negativa)

  $\rightarrow e_h \geq 4,0cm$

- $e_h = 14 - 2.Cobr - 2.\phi t - 2.1,25 = 4,5cm \Rightarrow 4,5cm > 4,0cm \rightarrow OK$

- $d'_r = Cobr + \phi t + \frac{0,8}{2} = 3,90cm \rightarrow 3,9cm < 5,0cm \rightarrow OK$

- $a = 0 \rightarrow 0 < 5\%.h = 2,0cm \rightarrow OK$ (Rcc $\leftrightarrow$ CG)