

→ Fórmula Direta

1)  $b = 20 \text{ cm}$        $M_K = 200 \text{ KN} \cdot \text{m}$       CA-50A.  
 $h = 60 \text{ cm}$        $N_K = 790 \text{ KN} \cdot \text{m}$   
 $d' = 3 \text{ cm}$        $f_{ck} = 20 \text{ MPa}$

$$f_{ck} = 2 \text{ KN/cm}^2$$

$$M_d = 20000 \text{ KN} \cdot \text{cm} \cdot 1,4 \Rightarrow M_d = 28000 \text{ KN} \cdot \text{cm} \quad f_{cd} = 1,429 \text{ KN/cm}^2$$

$$N_d = 790 \text{ KN} \cdot 1,4 \Rightarrow N_d = 1106 \text{ KN}$$

$$M_{sd} = 28000 + 1106(57 - 60/2) \Rightarrow M_{sd} = 57862 \text{ KN} \cdot \text{cm}$$

$$\mu_d = \frac{57862}{1,429 \cdot 20 \cdot 57^2} \Rightarrow \boxed{\mu_d = 0,623}$$

$$K_{x, \text{lim}} = 0,628$$

$$\mu_{d, \text{lim}} = 0,32$$

$$\nu_d = \frac{1106}{1,429 \cdot 20 \cdot 57} \Rightarrow \boxed{\nu_d = 0,679}$$

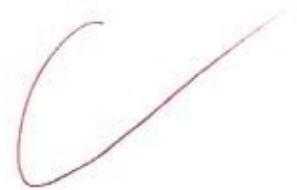
$$\text{Se } K_x \leq K_{x, \text{lim}} \Rightarrow E_{s,d} > E_{y,d} \quad \text{CA-50A}$$

$$w' = \frac{0,623 - 0,32}{1,058(1 - 3/57)} \Rightarrow \boxed{w' = 0,32}$$

$$w = 0,68 \cdot 0,623 + 0,32 - 0,679 \Rightarrow \boxed{w = 0,068}$$

$$A_s = 0,068 \cdot 20 \cdot 57 \cdot \frac{1,429}{43,478} \Rightarrow \boxed{A_s = 2,563 \text{ cm}^2}$$

$$A'_s = 0,32 \cdot 20 \cdot 57 \cdot \frac{1,429}{43,478} \Rightarrow \boxed{A'_s = 11,99 \text{ cm}^2}$$



2)  $b = 20 \text{ cm}$        $M_k = 169 \text{ kN.m}$       CA-50A  
 $h = 60 \text{ cm}$        $N_k = 300 \text{ kN}$   
 $d' = 3 \text{ cm}$        $f_{ck} = 20 \text{ MPa}$

$$M_d = 16900 \cdot 1,4 \Rightarrow M_d = 2366 \text{ kN.cm}$$

$$N_d = 300 \cdot 1,4 \Rightarrow N_d = 420 \text{ kN}$$

$$M_{sd} = 2366 + 420 (57 - 30) \Rightarrow M_{sd} = 35000 \text{ kN.cm}$$

$$\mu_d = \frac{35000}{1,429 \cdot 20 \cdot 57^2} \Rightarrow \boxed{\mu_d = 0,377} \quad \mu_{d, \text{lim}} = 0,32$$

$$\nu_d = \frac{420}{1,429 \cdot 20 \cdot 57} \Rightarrow \boxed{\nu_d = 0,258}$$

$$\omega = \frac{0,377 - 0,32}{(1 - 3/57)} \Rightarrow \boxed{\omega = 0,060}$$

$$\omega = 0,68 \cdot 0,6234 + 0,06 - 0,258 \Rightarrow \omega = 0,229$$

$$A_s = 0,229 \cdot 20 \cdot 57 \cdot \frac{1,429}{43,478} \Rightarrow \boxed{A_s = 8,595 \text{ cm}^2}$$

$$A'_s = 0,060 \cdot 20 \cdot 57 \cdot \frac{1,429}{43,478} \Rightarrow \boxed{A'_s = 2,248 \text{ cm}^2}$$



# Zonas de Solicitação (Armadura Assimétrica) ②

$$\begin{array}{l} b = 20 \text{ cm} \\ h = 60 \text{ cm} \\ d' = 3 \text{ cm} \end{array} \quad \begin{array}{l} f_{ck} = 20 \text{ MPa} \\ \alpha_s = 57 \text{ A} \end{array} \quad \left\{ \begin{array}{l} K_{x \text{ lim}} = 0,6284 \\ K_h = 1,053 \end{array} \right.$$

3)  $M_K = 90 \text{ kN.m}$        $N_K = 1400 \text{ kN}$

1-as)

$$M_d = 9000 \cdot 1,4 \Rightarrow M_d = 12600 \text{ kNcm}$$

$$N_d = 1400 \cdot 1,4 \Rightarrow N_d = 1960 \text{ kN}$$

$$\mu_d = \frac{12600}{1,429 \cdot 20 \cdot 57^2} \Rightarrow \mu_d = 0,136/$$

$$\nu_d = \frac{1960}{1,429 \cdot 20 \cdot 57} \Rightarrow \nu_d = 1,203/$$

Testes para a Zona de Solicitação

$$p \Rightarrow 0,85 K_h = 0,895 < \nu_d = 1,203 \therefore \text{Zonas A, B ou C} \Rightarrow$$

Limite da zona A  $\Rightarrow$

$$\mu_{dAB} = (1 - 0,5 K_h) (\nu_d - 0,85 K_h) \Rightarrow \mu_{dAB} = (1 - 0,527) (1,203 - 0,895) \Rightarrow$$

$$\mu_{dAB} = 0,146 > \mu_d \Rightarrow \text{Zona "A"} //$$

$$w_1 = \frac{1}{2 \cdot 0,966} \left( 1,203 - \frac{0,136}{(1 - 0,5 \cdot 1,053)} - 0,85 \cdot 1,053 \right) \Rightarrow w_1 = 0,011/$$

$$w_2 = \frac{1}{2 \cdot 0,966} \left( 1,203 + \frac{0,136}{(1 - 0,5 \cdot 1,053)} - 0,85 \cdot 1,053 \right) \Rightarrow w_2 = 0,308/$$

$$A_{s1} = 0,011 \cdot 20 \cdot 57 \cdot \frac{1,429}{43,478} \Rightarrow \boxed{A_{s1} = 0,402 \text{ cm}^2}$$

$$A_{s2} = 0,308 \cdot 20 \cdot 57 \cdot \frac{1,429}{43,478} \Rightarrow \boxed{A_{s2} = 11,543 \text{ cm}^2}$$



4)  $NK = 790 \text{ KN}$        $MK = 140 \text{ KN.m}$

(12)

2-av)  
 $M_d = 14000 \cdot 1,4 \Rightarrow M_d = 19600 \text{ KN.cm}$   
 $N_d = 790 \cdot 1,4 \Rightarrow N_d = 1106 \text{ KN.cm}$

$$\mu_d = \frac{19600}{1,429 \cdot 20 \cdot 57^2} \Rightarrow \mu_d = 0,211/$$

$$\nu_d = \frac{1106}{1,429 \cdot 20 \cdot 57} \Rightarrow \nu_d = 0,679/$$

Todas las zonas de solicitación

1º  $0,85 \cdot K_h = 0,895 > 0,679$   
 2º  $0,68 \cdot K_{rel,m} = 0,427 < 0,679$  } Zonas 0, B, C

Límite de la zona C

$$\mu_{dBC} = (1 - 0,5 \cdot 1,053) \cdot 0,679 + 0,32 - 0,68 \cdot 0,6284 (2 - 1,053) \Rightarrow$$

$$\mu_{dBC} = 0,237 > 0,211 \Rightarrow$$

Límite de la zona 0

$$\mu_{d0} = -\frac{0,679^2}{1,7} + 0,5 \cdot 1,053 \cdot 0,679 \Rightarrow \mu_{d0} = 0,086 < 0,211 \Rightarrow \text{Zona B} \Rightarrow$$

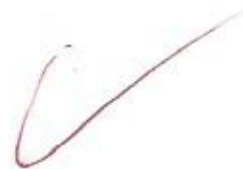
$$K_x = 1,25 (1,053 - 1) + \sqrt{(1,5625 (1,053 - 1)^2 + \frac{(0,679 - 0,5 \cdot 0,679 \cdot 1,053 - 0,211)^2}{0,272}} \Rightarrow$$

$$K_x = 0,707 < K_h \Rightarrow \text{Domín. n.º 4} \Rightarrow$$

$$E_{s2d} = \frac{(0,707 - 1,053 + 1) \cdot 3,5}{0,707} \Rightarrow E_{s2d} = 3,238 > 207 \Rightarrow \sigma_{s2d} = f_{yd} //$$

$$w_2 = 0,679 - 0,68 \cdot 0,707 \Rightarrow w_2 = 0,193/$$

$$A_{s2} = 0,198 \cdot 20 \cdot 57 \cdot \frac{1,429}{43,478} \Rightarrow A_{s2} = 7,428 \text{ cm}^2 //$$



5)  $N_k = 790 \text{ kN}$      $M_k = 200 \text{ kN.m}$

3-as)  $M_d = 20000 \text{ N.m}$      $M_d = 20000 \text{ kN.m}$

$N_d = 790 \text{ N}$      $N_d = 790 \text{ kN}$

$\mu_d = \frac{20000}{1429 \cdot 20 \cdot 57^2} \Rightarrow \mu_d = 0,302/$

$\nu_d = \frac{790}{1429 \cdot 20 \cdot 57} \Rightarrow \nu_d = 0,679/$

Testar as zonas de solicitação

1º  $0,85 \cdot k_h = 0,895 > \nu_d$  } ZONE D, E, C

2º  $0,68 \cdot k_{rel,m} = 0,927 < \nu_d$

$\mu_{do} = \frac{-0,679^2}{1,7} + 0,5 \cdot 0,53 \cdot 0,679 \Rightarrow \mu_{do} = 0,036 < \mu_d \Rightarrow \text{ZONA B ou C}$

$\mu_{dec} = (1 - 0,5 \cdot 0,53) \cdot 0,679 + 0,32 - 0,68 \cdot 0,6234 \cdot (2 - 0,53) \Rightarrow \mu_{dec} = 0,237 < \mu_d$

↓  
ZONA "C"

$w_1 = \frac{0,302 - 0,68 \cdot 0,6234 \cdot (1,053 - 1 - 0,4 \cdot 0,6234) - 0,679 \cdot (1 - 0,5 \cdot 0,53)}{(2 - 0,53)}$

$w_1 = 0,069/$

$w_2 = 0,679 - 0,68 \cdot 0,6234 + 0,069 \Rightarrow w_2 = 0,325/$

$A_{s1} = 0,069 \cdot 20 \cdot 57 \cdot \frac{1429}{43,478} \Rightarrow A_{s1} = 2,595 \text{ cm}^2$

$A_{s2} = 0,325 \cdot 20 \cdot 57 \cdot \frac{1429}{43,478} \Rightarrow A_{s2} = 12,027 \text{ cm}^2$

\* A diferença é devido ao arredondamento //



6)  $N_k = 300 \text{ kN}$   $M_k = 112 \text{ kN.m}$

4-as)  $N_d = 300 \cdot 1,4 \Rightarrow N_d = 420 \text{ kN}$

$M_d = 11200 \cdot 1,4 \Rightarrow M_d = 15680 \text{ kN.cm}$

$\mu_d = \frac{15680}{4429,20 \cdot 57^2} \Rightarrow \mu_d = 0,169$

$\nu_d = \frac{420}{4429,20 \cdot 57} \Rightarrow \nu_d = 0,258$

Teste das zonas de solicitação

1º  $0,85 \cdot K_h = 0,895 >> 0,258$

2º  $0,68 \cdot K_{cl,m} = 0,427 >> 0,258$

3º  $\nu_d > 0 \Rightarrow \text{Zonas D, D_{ac}}$

Limites das zonas de solicitação

$\mu_{do} = -\frac{0,258^2}{17} + 0,5 \cdot 0,53 \cdot 0,258 \Rightarrow \mu_{do} = 0,097 < 0,169 \Rightarrow \text{Zona D}_{ac}$

$\mu_{eco} = -(1 - 0,5 \cdot 0,53) \cdot 0,258 + 0,32 \Rightarrow \mu_{eco} = 0,198 > 0,169 \Rightarrow \text{Zona "D"}$

$K_x = 1,25 - \sqrt{1,5625 - \frac{(0,258(1 - 0,5 \cdot 0,53) + 0,169)}{0,272}} \Rightarrow K_x = 0,549$

$w_s = \frac{0,68 K_x - \nu_d}{\frac{\sigma_{ssd}}{f_{yd}}} \Rightarrow K_x < K_{x,lim} \Rightarrow$

$w_s = 0,68 \cdot 0,549 - 0,258$

$w_s = 0,115$

$E_{ssd} = \frac{(1 - 0,549) \cdot 3,5}{0,549} \Rightarrow E_{ssd} = 2,88 > 2,07$

$\sigma_{ssd} = f_{yd}$

$A_{ss} = 0,115 \cdot 20 \cdot 57 \cdot \frac{1429}{43478} \Rightarrow A_{ss} = 4,32 \text{ cm}^2$



$$7) N_k = -490 \text{ kN} \quad M_k = 300 \text{ kN}\cdot\text{m}$$

$$7\text{-as)} N_d = -490 \cdot 1,4 \Rightarrow N_d = -686 \text{ kN}$$

$$M_d = 30000 \cdot 1,4 \Rightarrow M_d = 34000 \text{ kN}\cdot\text{cm}$$

$$\mu_d = \frac{34000}{3429 \cdot 20 \cdot 57^2} \Rightarrow \mu_d = 0,153/$$

$$\nu_d = \frac{-686}{3429 \cdot 20 \cdot 57} \Rightarrow \nu_d = -0,423/$$

Todos las Zonas de Solidaridad

$$\rightarrow \nu_d < 0 \Rightarrow \text{Zonas E, D y C}$$

Límites de las zonas de solidaridad =

$$\mu_{d0E} = -(1 - 0,5 \cdot 1,053) \cdot (-0,423) \Rightarrow \mu_{d0E} = 0,199 > \mu_d \rightarrow \text{ZONA "E"}$$

$$w_1 = \frac{-(-0,423) \cdot (1 - 0,5 \cdot 1,053) + 0,153}{(2 - 1,053)} \Rightarrow w_1 = 0,370/$$

$$w_2 = \frac{-(-0,423) \cdot (1 - 0,5 \cdot 1,053) - 0,153}{(2 - 1,053)} \Rightarrow w_2 = 0,053/$$

$$A_{s1} = 0,37 \cdot 20 \cdot 57 \cdot \frac{3429}{43,478} \Rightarrow \boxed{A_{s1} = 33,862 \text{ cm}^2}$$

$$A_{s2} = 0,053 \cdot 20 \cdot 57 \cdot \frac{3429}{43,478} \Rightarrow \boxed{A_{s2} = 1,953 \text{ cm}^2}$$



8)  $M_K = 90 \text{ kN.m}$   $N_K = 1400 \text{ kN}$

1-5)  $\mu_d = 0,136$   $\mu_c = 1,203$   $\mu_{d+c} = 0,952 < 1,203 \rightarrow \text{ZONA A ou C}$

Limites das zonas de solicitação

$\mu_{d+c} = 0,68 \cdot 1,053 - 0,952 + (1 - 0,52 \cdot 1,053) \cdot 1,203 \Rightarrow \mu_{d+c} = 0,334 > 0,136$

Solução por método de Jôss

ZONA A

2) Equação balanceada (Limite entre os Domínios 4 e 5)  $K_x = K_h$

$\mu_d = 0,34 K_x \cdot (K_h - 0,8 K_x) + \frac{(\mu_c - 0,68 K_x) \cdot (1 - 0,5 K_h) \cdot (\alpha_2 - \alpha_1)}{(\alpha_1 + \alpha_2)}$

$\epsilon_{s,d} = \frac{(1,053 - 1) \cdot 3,5}{1,053} \Rightarrow \epsilon_{s,d} = 0,176\%$

$\frac{\sigma_{s,d}}{\sigma_{yd}} = \frac{0,176 \cdot 210000}{434,783 \cdot 1000} \Rightarrow \frac{\sigma_{s,d}}{\sigma_{yd}} = 0,085 = \alpha_1$

$\epsilon_{s,c} = \frac{(1,053 - 1,053 + 1) \cdot 3,5}{1,053} \Rightarrow \epsilon_{s,c} = 3,224\% \Rightarrow \alpha_2 = 1$

Substituímos na equação balanceada

$\mu_{d+5} = 0,075 + (\mu_d - 0,136) \cdot (0,399) \Rightarrow$

$\mu_{d+5} = 0,399 \mu_d - 0,2509 \Rightarrow$

$\mu_{d+5} = 0,269 > 0,136 \rightarrow \text{Domínio 5} \Rightarrow K_x > K_h$

$\Rightarrow$  Potência de Cálculo  $\Rightarrow$

$\epsilon_{s,d} = \frac{14(K_x - 1)}{7K_x - 3K_h} \Rightarrow \frac{\sigma_{s,d}}{\sigma_{yd}} = \frac{\epsilon_{s,d} \cdot 210000}{\sigma_{yd} \cdot 1000} = \alpha_1$

$\epsilon_{s,c} = \frac{14(K_x - K_h + 1)}{7K_x - 3K_h} \Rightarrow \frac{\sigma_{s,c}}{\sigma_{yd}} = \frac{\epsilon_{s,c} \cdot 210000}{\sigma_{yd} \cdot 1000} = \alpha_2$



$$\mu_d = 0,34 \cdot K_x \cdot (K_h - 0,8 K_x) + \frac{(\mu_d - 0,68 K_x) \cdot (1 - 0,5 K_h) \cdot (\alpha_2 - \alpha_1)}{(\alpha_2 + \alpha_1)}$$

$K_x$	$\alpha_1$	$\alpha_2$	$\mu_d$	$\varepsilon(\%)$
1,1	0,149	1	0,22427	64,904
1,2	0,258	1	0,24602	7,368
1,23	0,285	1	0,2537	-7,916
1,21	0,267	1	0,23903	2,232
1,214	0,271	1	0,23627	0,200

$$\omega = \frac{1003 - 0,68 \cdot 1,214}{0,271 + 1} \Rightarrow \omega = 0,297$$

$$A_s = 0,297 \cdot 20 \cdot 57 \cdot \frac{1429}{43476} \Rightarrow A_s = 11,128 \text{ cm}^2$$

$$A_{s2} = 22,256 \text{ cm}^2$$

9)  $N_K = 790 \text{ kN}$   $M_K = 140 \text{ kN.m}$

2-5)

$$\mu_d = 0,211$$

$$\mu_d = 0,679$$

1<sup>a</sup> ver de Zonas de Sollec. Longitudinal

$$1^a \Rightarrow 0,85 \cdot K_h = 0,895 > 0,679$$

$$2^a \Rightarrow 0,68 \cdot K_x \cdot l_{cr} = 0,427 < 0,679 \Rightarrow \text{ZONA A, D ou C}$$

$$\mu_{dAC} = 0,68 \cdot 1,053 - 0,952 + (1 - 0,5 \cdot 1,053) \cdot 0,679 \Rightarrow \mu_{dAC} = 0,086 < 0,211$$

ZONA "C"

$\rightarrow$  por cond. var  $\Rightarrow K_x = K_x \cdot l_{cr} \Rightarrow$  Domínio 3

$$\varepsilon_{sd} = \frac{(1 - K_x) \cdot 3,5}{K_x} \Rightarrow \alpha_1 = \frac{\varepsilon_{sd} \cdot 210}{\sigma_{yd}}$$

$$\varepsilon_{sd} = \frac{(K_x - K_h + 1) \cdot 3,5}{K_x} \Rightarrow \alpha_2 = \frac{\varepsilon_{sd} \cdot 210}{\sigma_{yd}}$$

$$\mu_d = 0,34 \cdot K_x \cdot (K_h - 0,8 K_x) + \frac{(\mu_d - 0,68 K_x) \cdot (1 - 0,5 K_h) \cdot (\alpha_2 + \alpha_1)}{(\alpha_2 - \alpha_1)}$$

$Kx$	$\alpha_1$	$\alpha_2$	$\mu d$	$E(\%)$
* 0,6264	1	1	E	-
0,75	0,564	1	0,40256	90,789
0,85	0,298	1	0,29629	-6,974
0,835	0,334	1	0,23477	1,791
0,837	0,329	1	0,23236	0,554
0,8372	0,3287	1	0,23190	0,431

→ OK!!

$$w = \frac{0,231 - 0,34 \cdot 0,8372 (1,053 - 0,8 \cdot 0,8372)}{(1 + 0,3287) \cdot (1 - 0,5 \cdot 1,053)} \Rightarrow$$

$$w = 0,162$$

$$A_s = 0,162 \cdot 2057 \cdot \frac{1429}{43440} \Rightarrow A_s = 6,069 \text{ cm}^2$$

$$A_s = 12,138 \text{ cm}^2 //$$



JO)  $MK = 500 \text{ KN.m}$   $NK = -490 \text{ KN}$

7-s)  $\mu d = -0,425$   $\mu d < 0 \Rightarrow \text{ZONA E ou C}$   
 $w d = 0,1508$

$$w d_{ce} = (1,053 - 1) \cdot (0,952 - 0,272 \cdot 1,053) - (1 - 0,5 \cdot 1,053) \cdot (-0,425) \Rightarrow$$

$$w d_{ce} = 0,239 > 0,1508 \Rightarrow \text{ZONA E}$$

→ Solução por derivadas

$$E_{sd} = \frac{(K_h - 1 - K_x) \cdot 50\%}{1 - K_x} \Rightarrow \alpha_2 = \frac{E_{sd} \cdot 250}{f_{yd}}$$

$$\mu d = \beta_c \cdot 0,34 K_x \cdot (K_h - 0,8 K_x) + \frac{(\beta_c \cdot 0,60 K_x - \mu d) \cdot (1 - \alpha_2) \cdot (1 - 0,5 K_h)}{(1 + \alpha_2)}$$

$$Kh-1 = 0,053$$

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$$V/\beta_c = 1 \Rightarrow$$

$$0 < K_z < Kh-1$$

$K_z$	$\alpha_2$	$\mu_2$	$E(\%)$
0,03	0,115	0,1769	17,073
0,015	0,116	0,14534	-3,618
0,018	0,112	0,16123	0,291
0,0176	0,114	0,15014	-0,236
0,01779	0,113	0,15082	0,014

→ OK!!

$$w = \frac{0,68 \cdot 0,01779 \cdot 1 - (-0,421)}{1 + 0,113} \Rightarrow$$

$$w = 0,369\%$$

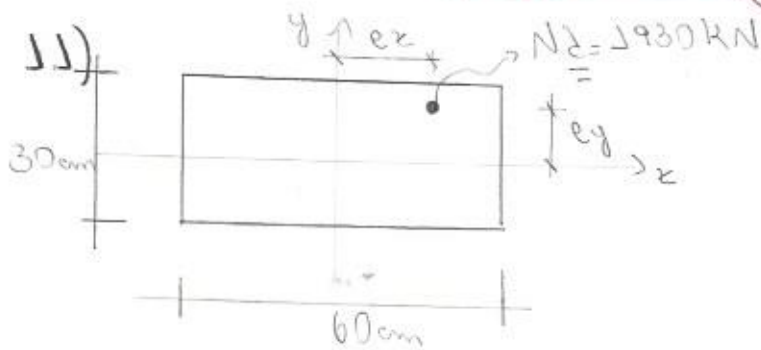
$$A_s = 0,369 \cdot 20 \cdot 57 \cdot \frac{1429}{43,418} \Rightarrow$$

$$A_s = 13,833 \text{ cm}^2 \Rightarrow A_{sd} = 27,665 \text{ cm}^2$$



flexão Oblíqua

CA-SOB



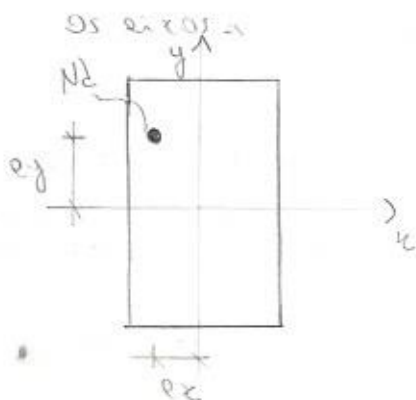
$$e_x = 5 \text{ cm}$$

$$e_y = 3 \text{ cm}$$

$$\nu_d = \frac{1930}{0,65 \cdot 1429 \cdot 60 \cdot 30} \Rightarrow \nu_d = 0,883\%$$

12) Verificação das eixos:

$$\frac{e_x}{h_x} > \frac{e_y}{h_y} \Rightarrow \frac{5}{60} > \frac{3}{30} \Rightarrow 0,083 > 0,1 \Rightarrow \tilde{N} \text{ verif. ca, } \therefore \text{inverter}$$



$$\frac{e_x}{h_x} > \frac{e_y}{h_y} \Rightarrow \frac{3}{30} > \frac{5}{60} \Rightarrow 0,1 > 0,083 \Rightarrow \text{verif. ca!!}$$

→ Solução definitiva →

$$1^a \text{ Interacao } \Rightarrow w = 0,50$$

$$e_{x,eq} = e_x + e_y \cdot \frac{h_x}{h_y} \cdot \beta$$

$\rightarrow$  pela NB-1  $\Rightarrow$

$$\left. \begin{array}{l} w = 0,5 \\ v_d = 0,75 \end{array} \right\} \beta = 60,5 \Rightarrow \beta_f = 0,605 //$$

$$e_{x,eq} = 3 + 5 \cdot \frac{30}{60} \cdot 0,605 \Rightarrow e_{x,eq} = 4,513 \text{ cm}$$

$$\mu_d = \frac{0,883 \cdot 4,513}{30} \Rightarrow \mu_d = 0,133 //$$



$$\delta = \frac{d'}{h} \Rightarrow \delta = \frac{3}{30} \Rightarrow \delta = 0,1$$

DA Tabela I-26  $\Rightarrow$

$$A_s = \rho \cdot A_c \quad ; \quad \rho = \bar{\rho} \cdot f_{ck} (\text{kg/cm}^2)$$

0,15	3,79	...	5,01
0,33	2,80	3,91	4,529
0,1	1	...	2,42
$\mu_d$	0,8	0,883	0,9

$$\bar{\rho} = 3,91 \%$$

$$\rho = 0,0391 \cdot 20 \Rightarrow \rho = 0,782 \%$$

$$A_s = 0,00782 \cdot 30 \cdot 60 \Rightarrow A_s = 14,076 \text{ cm}^2$$

$$A_\phi = \frac{14,076}{16} \Rightarrow A_\phi = 0,88 \text{ cm}^2$$

$$w = \frac{A_s \cdot f_{yd}}{A_c \cdot f_{ctd}} \Rightarrow w = \frac{14,076 \cdot 43,478}{30 \cdot 60 \cdot 2,429} \Rightarrow w = 0,238 //$$

$w_{lim,cal} \gg w_{calculado} \Rightarrow$

$w_{lim,cal} = 0,238 \rightarrow$  Atende o processo.

→ B → da tabela da NB-1

(2)

$$\left. \begin{array}{l} \mu = 0,883 \\ w = 0,238 \end{array} \right\}$$

$w \backslash \mu$	0,8	0,883	0,9
0	40	40	40
0,238	49,52	43,999	43,904
0,25	50	43,36	42

$$B = 43,999$$

$$e_{x,eq} = 3 + 0,432 \cdot 5 \cdot \frac{30}{60} \Rightarrow e_{x,eq} = 4,080 \text{ mm}$$

$$\mu = \frac{0,883 \cdot 4,080}{30} \Rightarrow \mu = 0,120 /$$

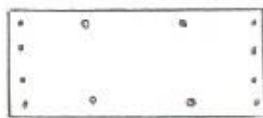


Tabela I-20

$$\delta = \frac{1}{n} \Rightarrow \delta = 0,1$$

0,25	3,75		4,98
0,22	2,2	3,206	3,432
0,20	1,		2,4
$w \backslash \mu$	0,8	0,883	0,9

$$\bar{\rho} = 3,206 \%$$

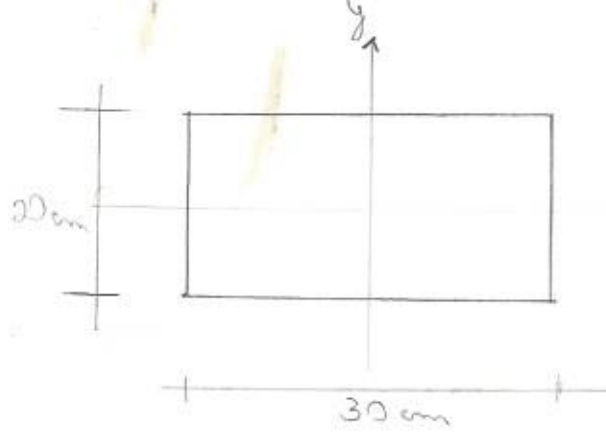
$$\rho = 0,03206 \cdot 20 \Rightarrow \rho = 0,6412 \%$$

$$A_s = 0,006412 \cdot 30 \cdot 60 \Rightarrow A_s = 11,542 \text{ cm}^2$$

$$A_{\phi} = \frac{11,542 \text{ cm}^2}{12} \Rightarrow A_{\phi} = 0,962 \text{ cm}^2 \quad ? *$$

$$w =$$





$N_R = 964,6 \text{ kN}$

$N_d = 964,6 \text{ kN}$

$M_{xR} = N_d \cdot e_x$

$M_{yR} = N_d \cdot e_y$

$M_{yR} = 26 \text{ kN} \cdot 3 \text{ m}$

$M_{xR} = 30 \text{ kN} \cdot 3 \text{ m}$

$M_{xR} = 30 \text{ kN} \cdot \text{m} \Rightarrow M_{xR} = 42 \text{ kN} \cdot \text{m} \Rightarrow M_{xR} = 4200 \text{ kN} \cdot \text{cm} //$

$M_{yR} = 48 \text{ kN} \cdot \text{m} \Rightarrow M_{yR} = 67,2 \text{ kN} \cdot \text{m} \Rightarrow M_{yR} = 6720 \text{ kN} \cdot \text{cm} //$

$e_x = \frac{4200}{964,6} \Rightarrow \boxed{e_x = 4,354 \text{ cm}}$

$\frac{e_x}{h_x} > \frac{e_y}{h_y} \Rightarrow \frac{4,354}{30} > \frac{6,967}{20}$

$e_y = \frac{6720}{964,6} \Rightarrow \boxed{e_y = 6,967 \text{ cm}}$

$0,145 > 0,348 \Rightarrow$

→ Inverted axes →

$e_x = 6,967, h_x = 20$

$e_y = 4,354, h_y = 30$

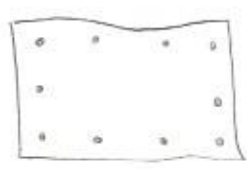
$\nu_d = \frac{964,6}{20 \cdot 30} = 1,607$

→ 1° Iteration →

$w = 0,5 \quad \beta = 0,40$

$e_x, e_y = e_x + e_y \frac{h_x}{h_y} \beta \Rightarrow e_x, e_y = 6,967 + 4,354 \cdot \frac{20}{30} \cdot 0,4 \Rightarrow e_x, e_y = 8,128$

$\nu_d = \frac{1,607 \cdot 8,128}{20} \Rightarrow \nu_d = 0,657$



→ Tabelle IJG  
 $\delta = 0,2$

$\bar{\rho} = 25,17075\%$

$\rho = 0,2517075 \cdot 20 =$

$\rho = 5,034\%$

$A_s = 0,05034 \cdot 20 \cdot 30 \Rightarrow A_s = 30,204 \text{ cm}^2$

0,5	27,22		28,74
0,457	29,9636	25,17075	26,0922
0,45	29,48		25,73
$\nu$	1,1	1,125	1,2

$w = \frac{30,204 \cdot 43,448}{20 \cdot 30 \cdot 1,607} \Rightarrow w = 1,53$