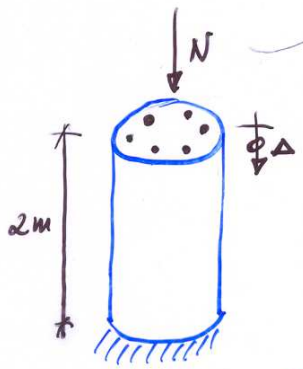
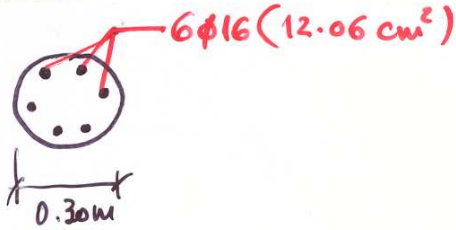
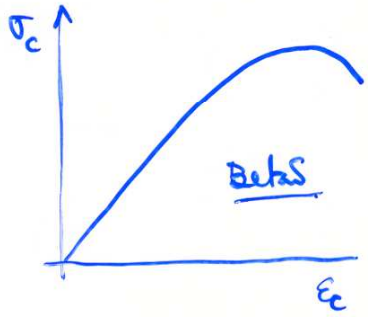


$\begin{cases} N_{GK} = 0 \\ N_{QK} = ? \end{cases}$ $(\psi_0 = 0.7;\ \psi_1 = 0.5;\ \psi_2 = 0.4)$

Materiais: $\begin{cases} C25/30 \\ S400 \end{cases}$



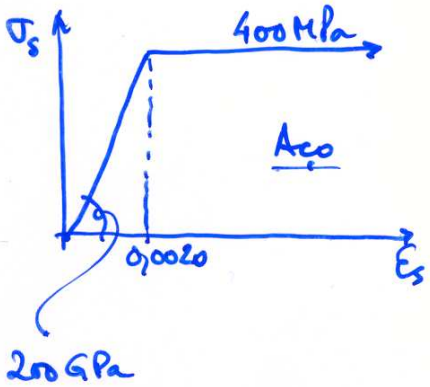
1) Diagrama N-Δ para análise estrutural (valores médios)



$$\frac{\sigma_c}{f_{cm}} = \frac{k\eta - \eta^2}{1 + (k-2)\eta}$$

$$k = 1{,}05\, E_{cm}\, \varepsilon_{c1} / f_{cm}$$

$\begin{cases} \varepsilon_{c1} = 0{,}0021 \\ E_{cm} = 31\ GPa \\ f_{cm} = 25 + 8 = 33\ MPa \end{cases}$



- Aderência perfeita + Secção plana ⇒ $\varepsilon = \varepsilon_s = \Delta/2$

- Equilíbrio ⇒ $N = \sigma_c \cdot A_c + \sigma_s \cdot A_s$

$A_c = \frac{\pi \times 0{,}33^2}{4} - 12{,}06\times10^{-4} = 0{,}0695\ m^2$

Δ (cm)	$\varepsilon = \varepsilon_c = \varepsilon_s$	σ_c (MPa)	σ_s (MPa)	$N = \sigma_c A_c + \sigma_s A_s$ (kN)	
0,11	0,00055	15,5	110,0	1208	(1075 + 133)
0,22	0,0011	25,6	220,0	2046	(1780 + 266)
0,34	0,0017	31,6	340,0	2603	
0,44	0,0022	33,0	400,0	2776	(2294 + 482)
0,56	0,0028	31,4	400,0	2665	
0,66	0,0033	26,9	400,0	2353	
0,70	0,0035				

2) Resistências de cálculo

- Pilar

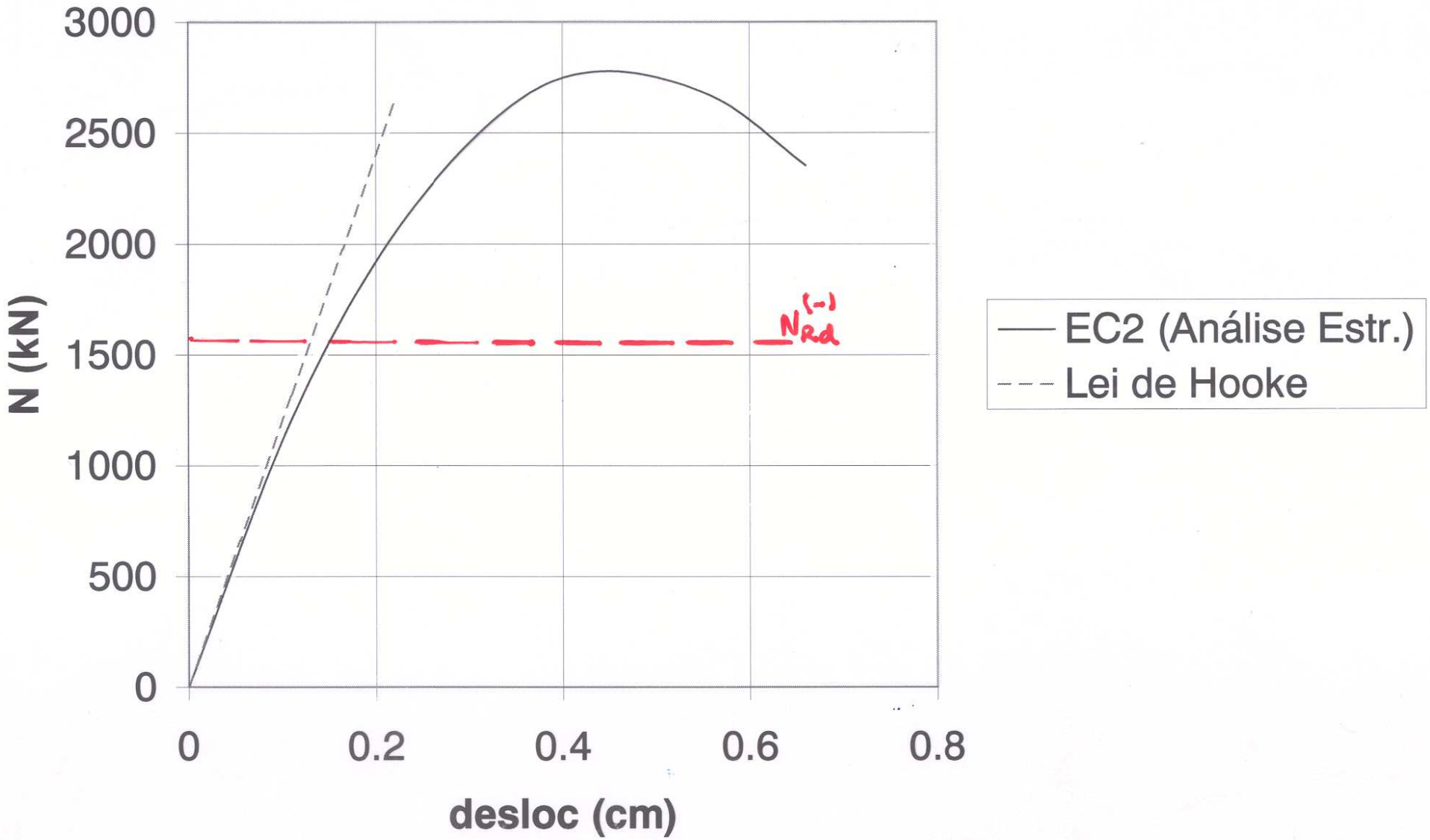
$$N_{Rd}^{(-)} = \cancel{0{,}85}\ f_{ck}/1.5\ A_c + f_{yd}\ (\text{ou } f_y|_{2‰}) \cdot A_s =$$

$$= \cancel{0{,}85} \times \frac{25\times10^3}{1.5} \times 0{,}0695 + \frac{400\times10^3}{1.15} \times 12{,}06\times10^{-4} = 1578\ kN$$

$f_{yd} = 348\times10^3$

- Tirante

$$N_{Rd}^{(+)} = f_{yd} \cdot A_s = 348\times10^3 \times 12.06\times10^{-4} = 420\ kN \quad (\simeq 27\%\ N_{Rd}^{(-)})$$


3000
2500
2000
1500
1000
500
0
N (kN)
0
0.2
0.4
0.6
0.8
desloc (cm)
$N_{Rd}^{(-)}$
EC2 (Análise Estr.)
Lei de Hooke

3) Esforço máximo N_{Qk} ($\psi_0 = 0.7$; $\psi_1 = 0.5$; $\psi_2 = 0.4$)

$$N_{Sd} = 1.35 \times N_{Gk} + 1.5 \times N_{Qk} \leq 1578 \text{ kN}$$

($N_{Gk} = 0$)

$$N_{Qk} \leq 1578 / 1.5 = 1052 \text{ kN}$$

4) Tensões na combinação quase permanente

$$N_{Cqp} = 0 + \psi_2 N_{Qk} = 0.4 \times 1052 = 420.8 \text{ kN}$$

$$A_{ci} = A_c - A_s + \alpha A_s = A_c + (\alpha - 1) A_s = \ldots$$

$$\alpha = \frac{E_s}{E_c}$$

- Sem fluência ($t = 0$) $E_c = 31 \text{ GPa} \; (= E_{cm})$

$$\alpha_0 = \frac{200}{E_c = 31} = 6.5$$

- Com fluência ($t = \infty$) $E_c = E_{c,eff} = \frac{E_{cm}}{1+\phi}$

$$\alpha_\infty = \frac{200}{E_{cm}} (1+\phi) = 18$$

($1.8 \times 12.06 \times 10^{-4}$)

- Sem fluência $A_{ci} = 0,0707 + (6.5 - 1) \times 12,06 \times 10^{-4} = 0,0774 \text{ m}^2$

$$\sigma_c^0 = \frac{N_{Cqp}}{0,0774} = 5,4 \text{ MPa} \quad (\leq 0.45 f_{ck} = 0.45 \times 25 = 11.25 \text{ MPa OK})$$

$$\sigma_s^0 = \alpha \sigma_c = 6,5 \times 5,4 = 35.1 \text{ MPa}$$

- Com fluência

$$A_{ci} = 0,0707 + (18 - 1) \times 1206 \times 10^{-4} = 0,0912 \text{ m}^2$$

$$\sigma_c^\infty = \frac{420.8}{0.0912} = 4.6 \text{ MPa} \searrow$$

$$\sigma_s^\infty = 18 \times 4.6 = 83.1 \text{ MPa} \nearrow$$