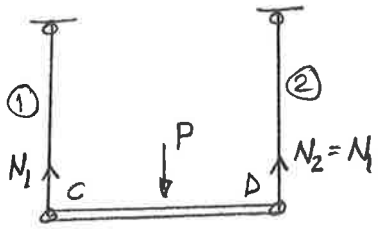
ETAPAS

A. até o fechamento da folga δ



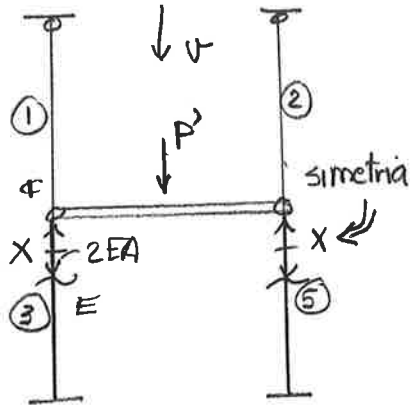
$$N_1 = N_2 = \frac{P}{2} \qquad \Delta\ell_1 = \frac{(\frac{P}{2})\ell}{EA} \Rightarrow P = \frac{2EA}{\ell}\delta$$

- no fechamento: $\delta = 0{,}1\ cm \Rightarrow P = \frac{2\times10^4\times10}{100}\times 0{,}1 = 200\ kN$
- acréscimos de N e σ

$$N_1 = N_2 = \frac{200}{2} = 100\ kN \qquad \sigma_1 = \frac{N_1}{A} = 10\ \frac{kN}{cm^2} \qquad \Delta\sigma_3 = 0$$

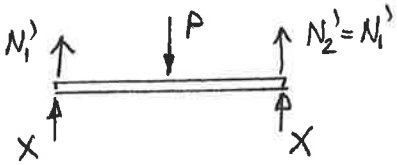
B. até o fechamento da folga 2δ

EIF_1



$v_C = v_E$

- Equilíbrio $\uparrow \{ 2N_1' + 2X = P'$



$$N_1' = N_2' = \frac{P'}{2} - X \qquad N_3' = N_5' = -X$$

- Eqs. constitutivas: $\Delta\ell_1 = \frac{(\frac{P'}{2}-X)\ell}{EA} \qquad \Delta\ell_2 = -\frac{X\ell}{2EA}$
- compatib. $\boxed{v_C = v_E} \Rightarrow \Delta\ell_1 = -\Delta\ell_3$

$$\frac{(\frac{P'}{2}-X)\ell}{EA} = \frac{X\ell}{2EA} \Rightarrow \frac{3}{2}\frac{X\ell}{EA} = \frac{P'\ell}{2EA} \Rightarrow X = \frac{P'}{3}$$

- no fechamento: $v_C = v_E = \delta \Rightarrow -\Delta\ell_3 = \delta$

$$\frac{X\ell}{2EA} = \delta \Rightarrow \frac{\frac{P'\ell}{3}}{2EA} = \delta \Rightarrow P' = \frac{6EA}{\ell}\delta = 600\ kN$$

- acréscimos de N e σ

$$N_1' = \frac{P'}{2} - X = 300 - 200 = 100\ kN \qquad N_3' = -X = -200\ kN$$

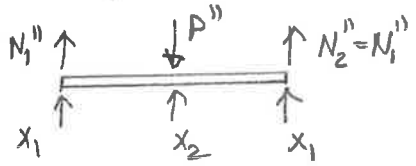
$$\sigma_1' = \frac{N_1'}{A} = 10\ \frac{kN}{cm^2} \qquad \sigma_3' = \frac{N_3'}{2A} = -10\ \frac{kN}{cm^2}$$

- acréscimo de v_Q

$$v_Q' = -\frac{\Delta\ell_5'}{2} = \frac{\frac{200\times100}{10^4\times20}}{2} = 0{,}05\ cm\ (\downarrow)$$

C. até P atingir 1600 kN (ou $P'' = 1600 - 200 - 600 = 800$ kN)

- Equilíbrio



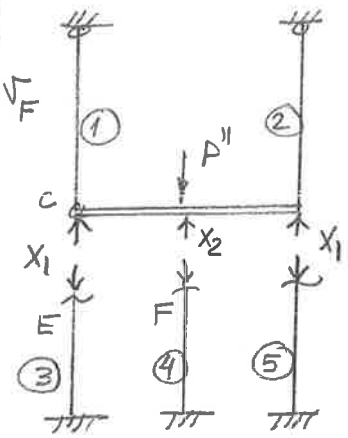
$N_1'' = \frac{P''}{2} - X_1 - \frac{X_2}{2}$

$N_3'' = -X_1$

$N_4'' = -X_2$

EIF_2

$v_C = v_E = v_F$



- Eqs. constitutivas

$\Delta l_1 = \frac{(\frac{P''}{2} - X_1 - \frac{X_2}{2})\,l}{EA}$ $\quad \Delta l_3 = \frac{(-X_1)\,l}{2EA}$ $\quad \Delta l_4 = \frac{(-X_2)\,l}{2EA}$

- Compatibili// $\boxed{v_C = v_E = v_F} \Rightarrow \Delta l_1 = -\Delta l_3 = -\Delta l_4$

$\Delta l_1 = -\Delta l_3$: $\frac{(\frac{P''}{2} - X_1 - \frac{X_2}{2})\,l}{EA} = \frac{X_1 l}{2EA} \Rightarrow \frac{3}{2}\frac{X_1 l}{EA} + \frac{X_2 l}{2EA} = \frac{P'' l}{2EA} \Rightarrow 3X_1 + X_2 = P''$ (1)

$-\Delta l_3 = -\Delta l_4$: $\frac{X_1 l}{2EA} = \frac{X_2 l}{2EA} \Rightarrow X_1 = X_2$ (2) em (1) $\Rightarrow X_1 = X_2 = \frac{P''}{4}$

- acréscimo de N e σ para $P'' = 800$ kN $\therefore X_1 = X_2 = 200$ kN

$N_1'' = N_2'' = 400 - 300 = 100$ kN $\quad \sigma_1'' = 10$ kN/cm²

$N_3'' = N_5'' = -200$ kN $\quad \sigma_3'' = -10$ kN/cm²

$N_4'' = -200$ kN $\quad \sigma_4'' = -10$ kN/cm²

- acréscimo de v_Q: $v_Q'' = -\frac{\Delta l_5''}{2} = \frac{\frac{200 \times 100}{10^4 \times 20}}{2} = 0{,}05$ cm (↓)