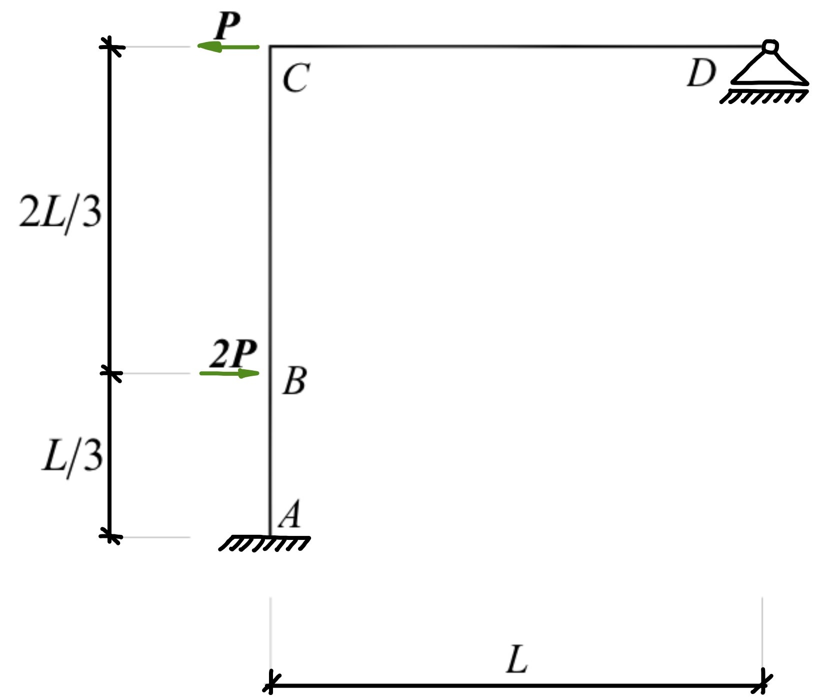
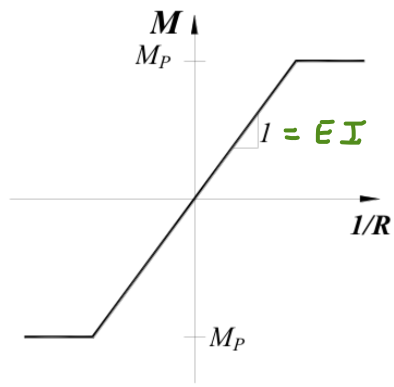
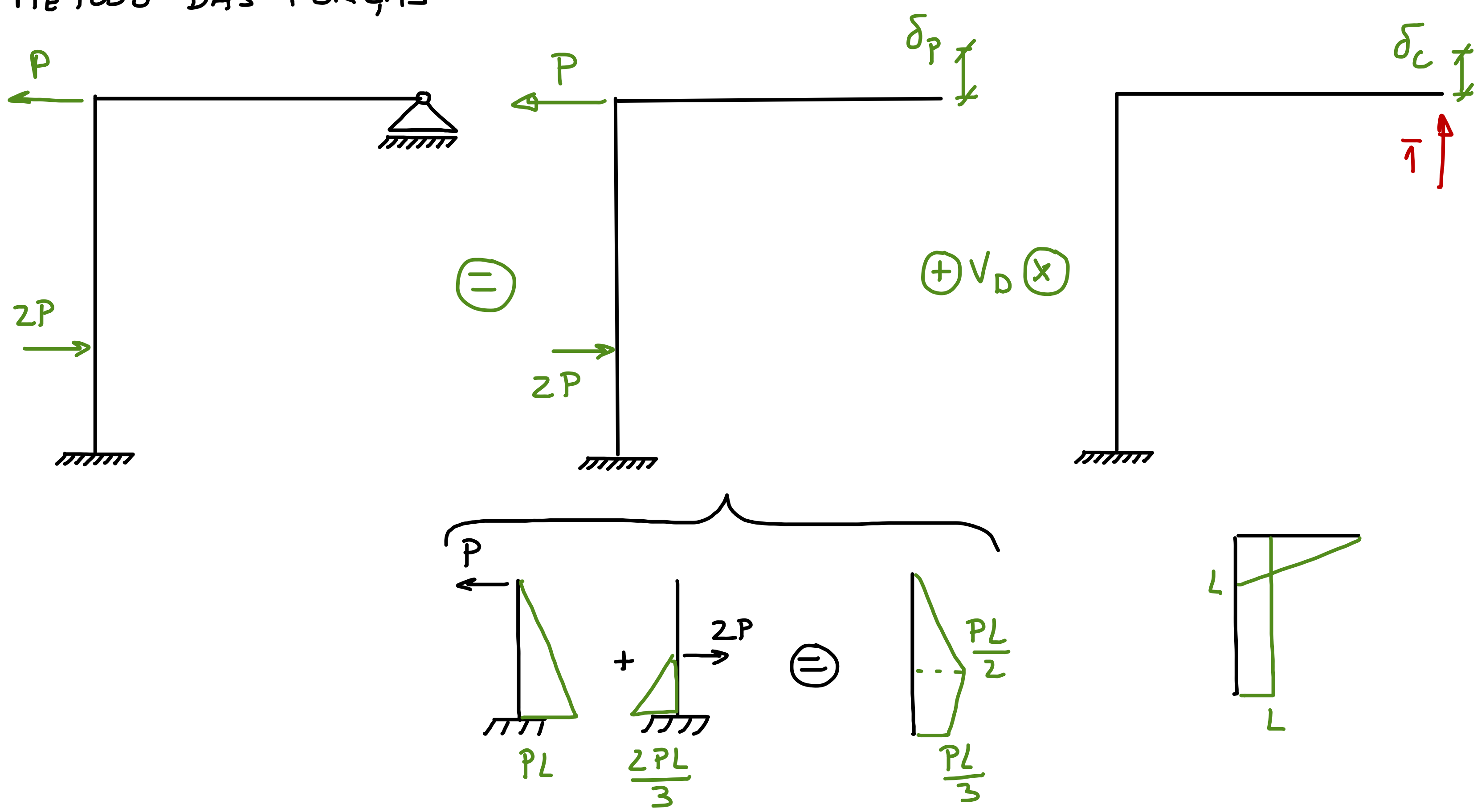




a) Diagrama elástico de momento flector:

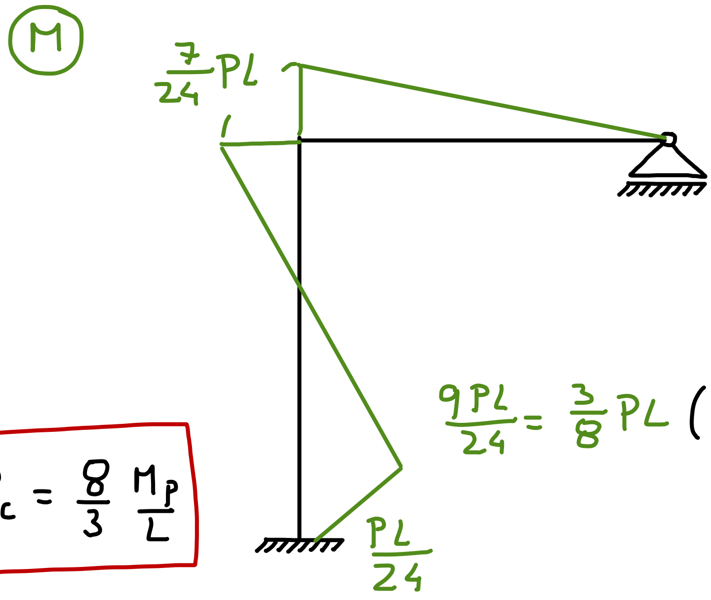
MÉTODO DAS FORÇAS



$$\delta_P = \sum \int \frac{M\bar{M}}{EI}\,dx = \int_L \ldots = \frac{1}{2}PL^3 - \frac{1}{2}\,\frac{L}{3}\,\frac{2PL}{3}\,L = \frac{7}{18}PL^3$$

$$\delta_C = \sum \int \frac{\bar{M}\bar{M}}{EI}\,dx = \int (\ldots)^2 + (\ldots)^2\,dx = L^3 + \frac{1}{3}L^3 = \frac{4}{3}L^3$$

$$\delta_P + V_D\,\delta_C = 0 \Rightarrow V_D = -\frac{7}{24}P\ (\downarrow)$$

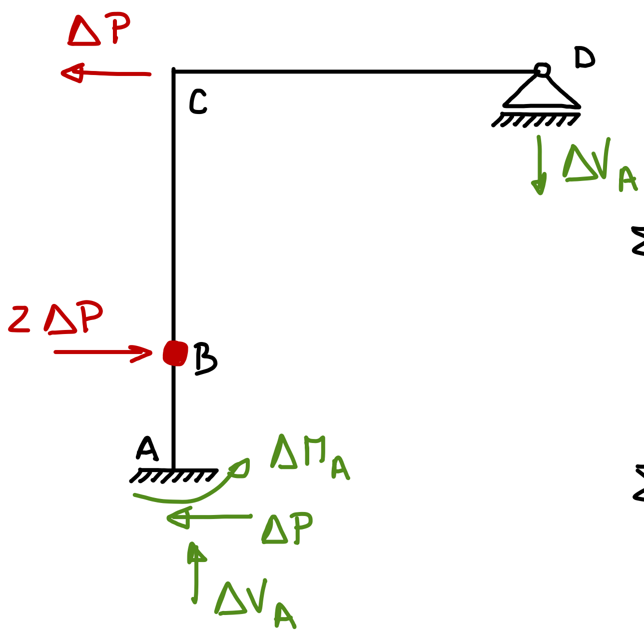


$$\frac{9PL}{24} = \frac{3}{8}PL \quad (M^{máx} \Rightarrow 1^a \text{ secção a plastificar})$$

$$\frac{3}{8}P_c L = M_p \Rightarrow \boxed{P_c = \frac{8}{3}\frac{M_p}{L}}$$

$$\boxed{P_{TOTAL} = P_c + \Delta P}$$

Análise incremental:



$$\Sigma F_H = 0 \Rightarrow \Delta H_A = \Delta P \ (\leftarrow)$$

$$\Sigma M_B^{\downarrow} = 0 \Rightarrow \Delta M_A = \frac{L}{3}\Delta P$$

$$\Sigma M_B^{\uparrow} = 0 \Rightarrow L\,\Delta V_A = \frac{2}{3}L\,\Delta P \Rightarrow \Delta V_A = \frac{2}{3}\Delta P$$

$$\Downarrow$$

$$\Delta M_c = -\frac{2}{3}\Delta P . L$$

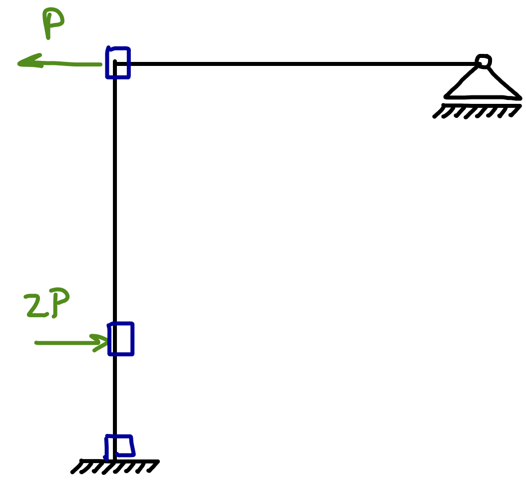
$$M_C = -\frac{7}{24}\,\frac{8}{3}M_p - \frac{2}{3}\Delta P.L = -\frac{7}{9}M_p - \frac{2}{3}\Delta P.L$$

$$M_A = \frac{1}{24}\,\frac{8}{3}M_p - \frac{L}{3}\Delta P = \frac{M_p}{L} - \frac{1}{3}\Delta P.L$$

CONCLUSÃO: a secção C plastifica primeiro do que a secção A

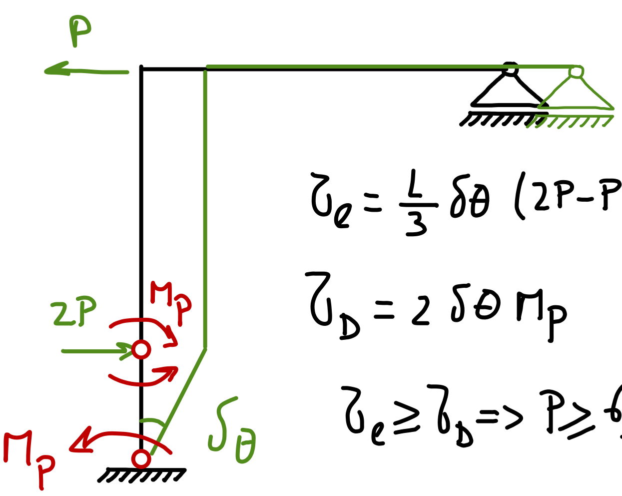
$$-\frac{7}{9}M_p - \frac{2}{3}\Delta P.L = -M_p \Rightarrow \Delta P = \frac{M_p}{3L} \Rightarrow P_M = \left(\frac{8}{3} + \frac{1}{3}\right)\frac{M_p}{L} = 3\,\frac{M_p}{L}$$

b) determinação carga colapso com teoremas A.L.



□ secção crítica

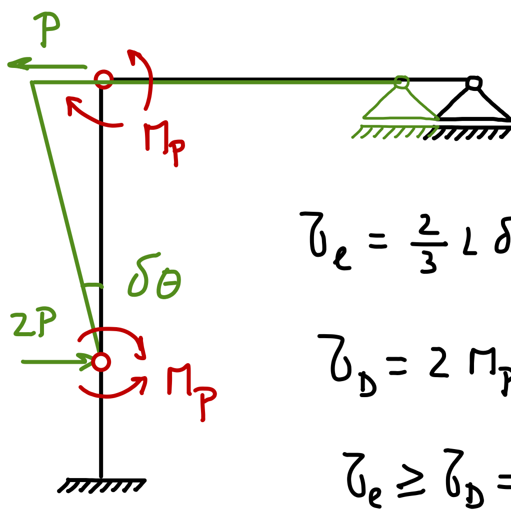
Nº. mecanismos = $C_2^3 = \frac{3!}{2!\,(3-2)!} = 3$



$$\tau_e = \frac{L}{3}\,\delta\theta\,(2P-P)$$

$$\tau_D = 2\,\delta\theta\, M_p$$

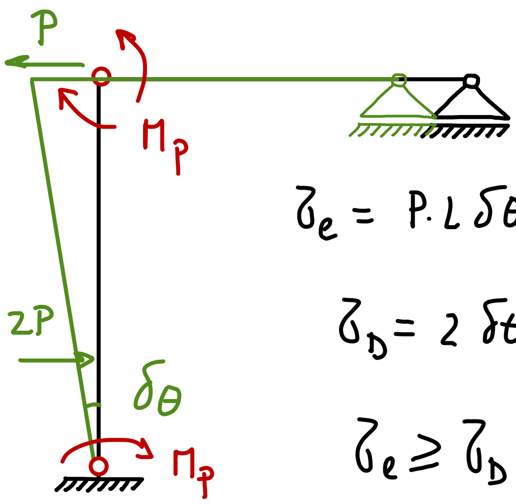
$$\tau_e \geq \tau_D \Rightarrow P \geq 6\,\frac{M_p}{L}$$



$$\tau_e = \frac{2}{3}\,L\,\delta_\theta\, P$$

$$\tau_D = 2\, M_p\, \delta\theta$$

$$\tau_e \geq \tau_D \Rightarrow P \geq \frac{3M_p}{L} \;//$$



$$\tau_e = P\cdot L\,\delta\theta - \frac{1}{3}L\,\delta\theta\cdot 2P$$

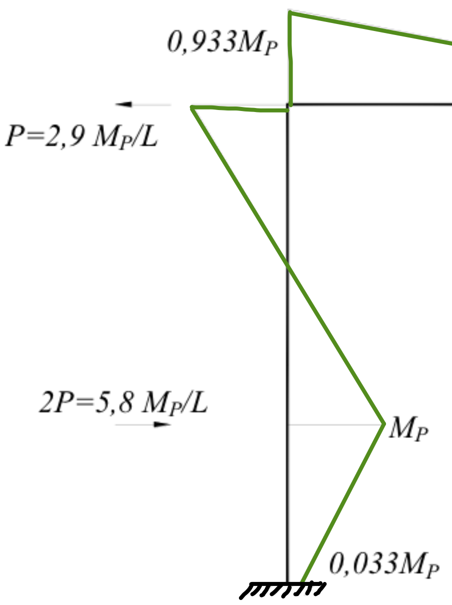
$$\tau_D = 2\,\delta\theta\, M_p$$

$$\tau_e \geq \tau_D \Rightarrow P \geq \frac{6M_p}{L}$$

NOTA: Não era necessário verificar este mecanismo porque não tem rótula em B (a 1ª secção a plastificar)

c) descarga:

⚠ a descarga é sempre realizada em regime elástico



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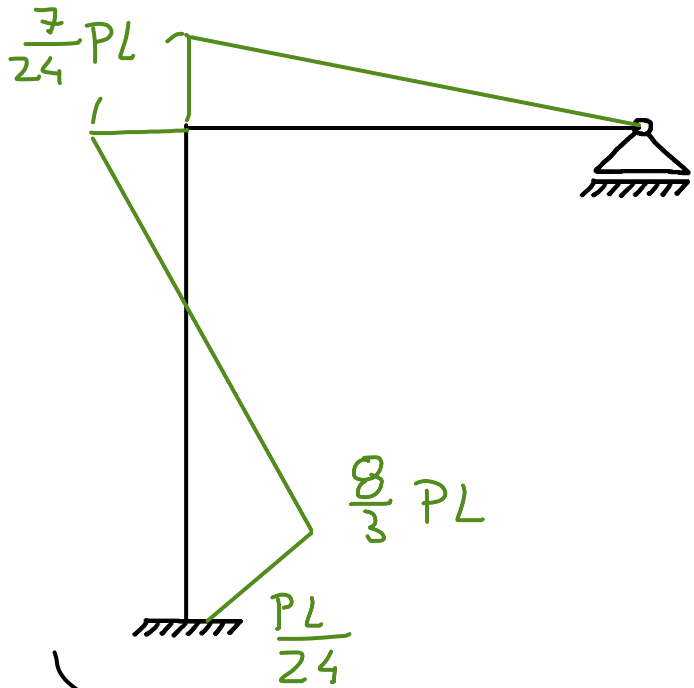

Esforços Elásticos com

$$\boxed{P = -\frac{2{,}9\,M_P}{L}}$$