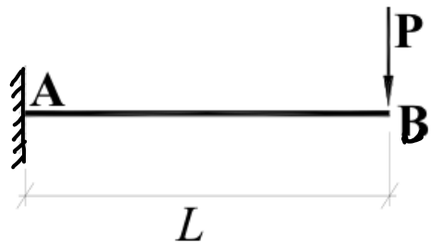
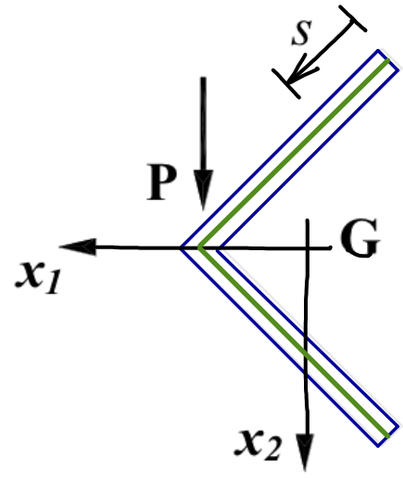
$L=2m$
$P=500\ kN$
$E=210\ GPa$
$\nu=0,3$



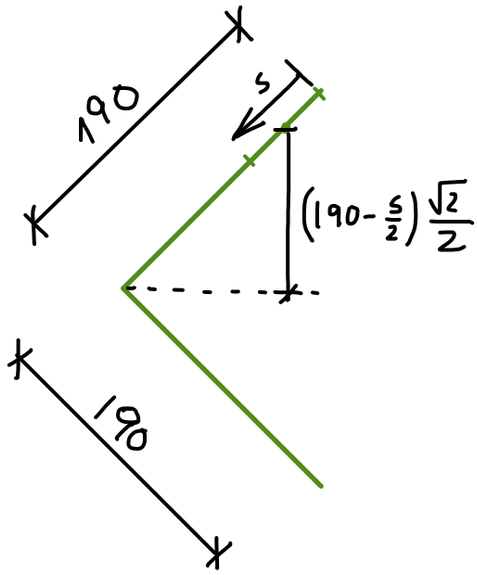


200 × 200 × 20

$I_1=45,32\times10^6\ mm^4$

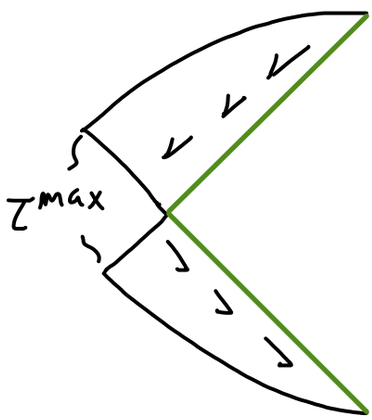
$G=\frac{E}{2(1+\nu)}\simeq 80,17$

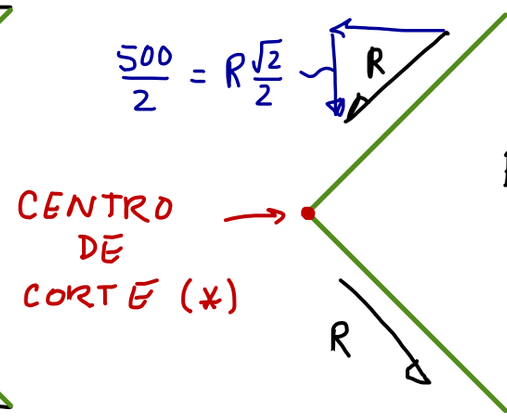
$$\tau=\frac{V_2\,S_1}{I_1\,e}$$



$$\tau=\frac{500\times10^3}{45,32\times10^6}\times\frac{(20\times s)\left(190-\frac{s}{2}\right)\frac{\sqrt{2}}{2}}{20}$$

$\tau^{max}=\tau\,(s=190)\simeq 139,2\ MPa$





$$R=\int_0^{190}\tau\times e\,ds=\frac{500}{\sqrt{2}}=353,6\ kN$$

$\int$ (139,2 × 1) ds

190

(*) Regras (para secção de parede fina): se (i) todos os troços convergirem num ponto ou (ii) existir plano de simetria, então o centro de corte localiza-se obrigatoriamente nessas zonas

ÁREA DE CORTE:

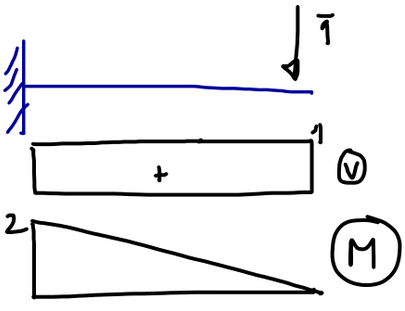
$$U = \frac{1}{2}\int_V \varepsilon \cdot \sigma \, dV + \frac{1}{2}\int \gamma \cdot \tau \, dV = \frac{1}{2}\int_L \int \frac{\sigma^2}{E} d\Omega \, dx_3 + \frac{1}{2}\int_L \int \frac{\tau^2}{G} d\Omega \, dx_3$$

$$\Rightarrow \underbrace{\frac{1}{2}\int_L \int \frac{N^2}{EA^2} d\Omega \, dx_3}_{\int_L \frac{N^2}{EA} dx_3} + \underbrace{\frac{1}{2}\int_L \int \frac{M^2}{EI^2} x^2 \, d\Omega \, dx_3}_{\int_L \frac{M^2}{EI} dx_3} + \underbrace{\frac{1}{2}\int_L \int \frac{V^2}{G}\frac{S^2}{I^2 e^2} d\Omega \, dx_3}_{\int_L \frac{V^2}{G A^*} dx_3}$$

$$A^* = \frac{I^2}{\int \frac{S^2}{e^2} d\Omega} = \frac{I^2}{\int \frac{S^2}{e} ds} = \frac{V_2^2}{\int \tau^2 d\Omega}$$

$$\int_\Omega \tau^2 d\Omega = 2e \int \left(\frac{139{,}2}{190}\right)^2 dx_3 = 0{,}02 \times 2 \times \frac{8}{15} \left(139{,}2 \times 10^3\right)^2 \times 0{,}19 = 78{,}54 \times 10^6 \; [kN^2/m^2]$$

$$A^* = \frac{500^2}{78{,}54 \times 10^6} = 3{,}183 \times 10^{-3} \; m^2$$



$$\delta = \int_L \frac{M\bar{M}}{EI} + \frac{V\bar{V}}{GA^*} dx_3$$

$$\delta = \int \frac{1}{EI} \underbrace{\frac{2 \times 500}{2}}_{2} \cdot 2 + \frac{1}{GA^*} 500 \cdot 1 \, dx_3$$

$$\delta = \underbrace{\frac{1}{EI}\frac{1}{3} 8 \times 500}_{140{,}1 \; mm} + \underbrace{\frac{1}{GA^*} 500 \times 2}_{3{,}89 \; mm} = 143{,}99 \; mm$$

$$\frac{143{,}99 - 140{,}1}{143{,}99} \times 100 = 2{,}7 \; \%$$