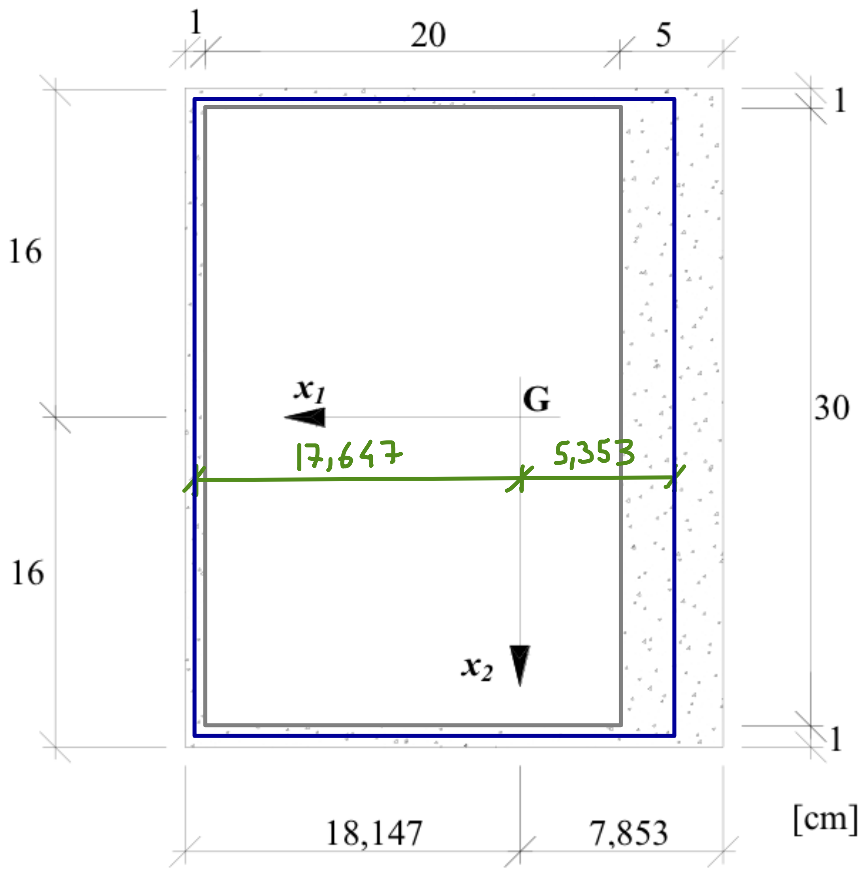
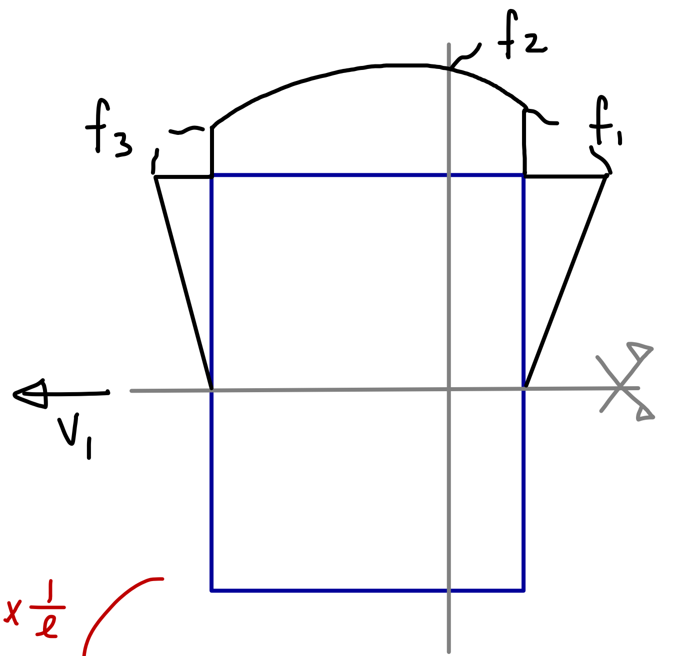
$$I_1 = 2{,}595 \times 10^{-4}\ m^4$$

$$I_2 = 1{,}819 \times 10^{-4}\ m^4$$



a) Represente o diagrama de tensões tangenciais da secção para:
 a.1) um esforço transverso de 500 kN segundo o eixo x_1;



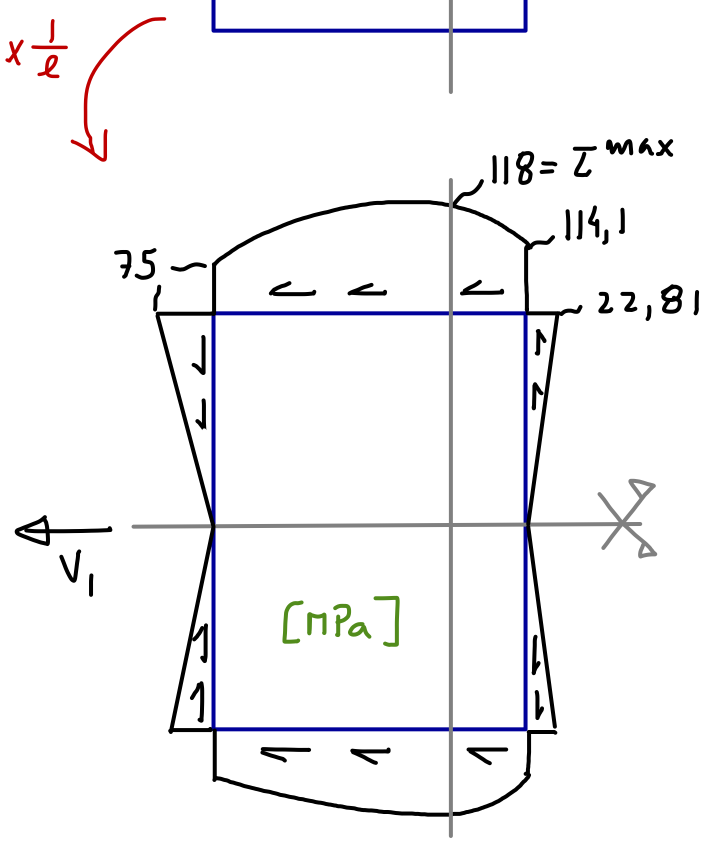
$$f_1 = \frac{V_1 \times 5{,}353\,(15{,}5 \times 5) \times 10^{6}}{1{,}819 \times 10^{-4}} = 2{,}281\,V_1$$

$$f_3 = \frac{V_1 \times 17{,}647\,(15{,}5 \times 1) \times 10^{6}}{1{,}819 \times 10^{-4}} = 1{,}5\,V_1$$

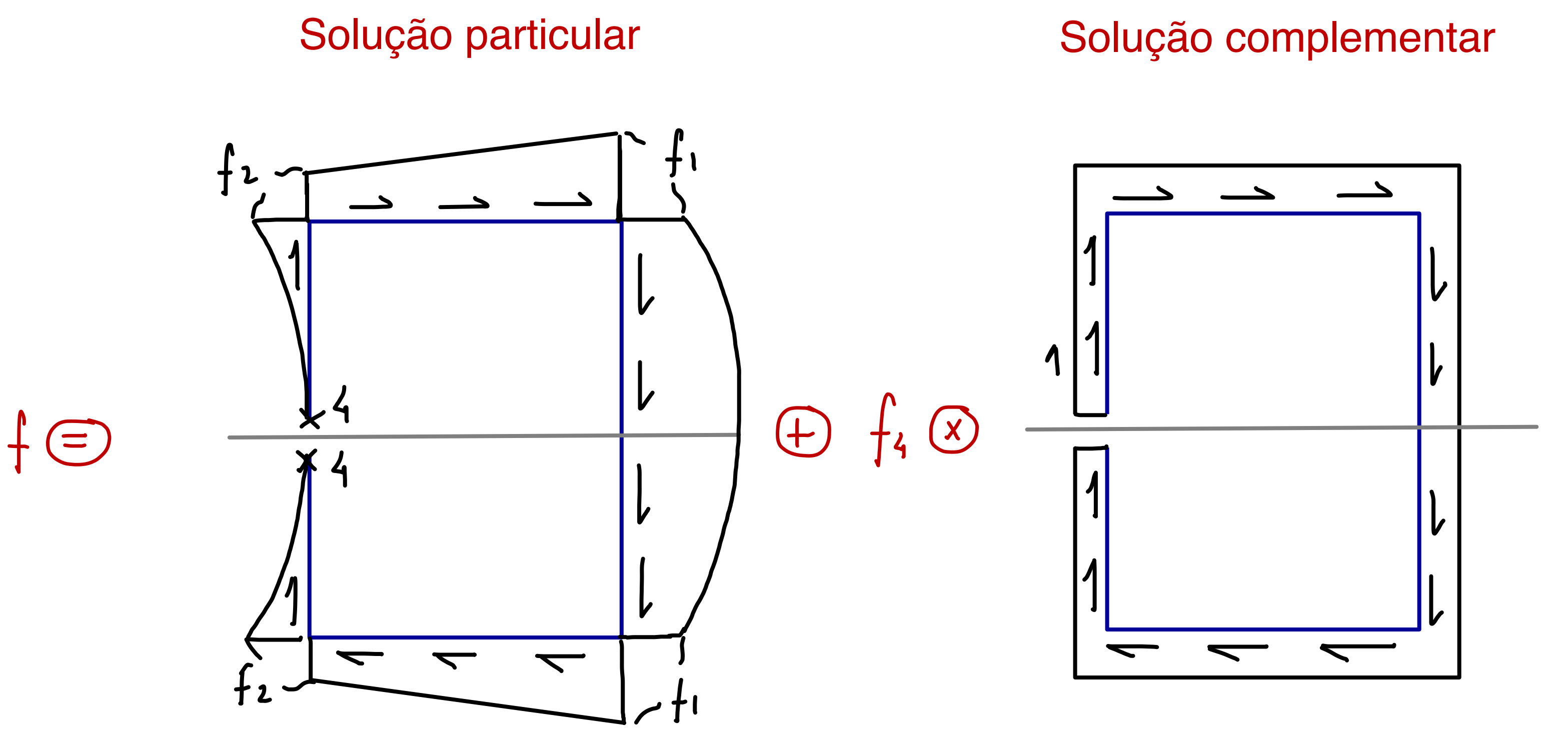
$$f_2 - f_1 = \frac{V_1 \times 5{,}353^2 \frac{1}{2} \times 1 \times 10^{-6}}{1{,}819 \times 10^{-4}} = 0{,}07876\,V_1$$

$$\Downarrow$$

$$f_2 = 2{,}36\,V_1$$



a.2) um esforço transverso de 500 kN segundo o eixo x_2

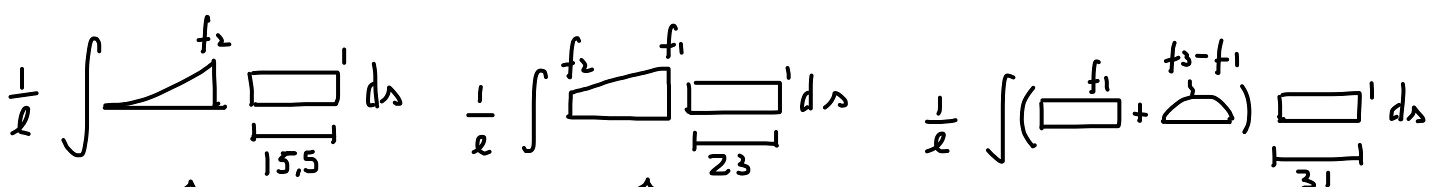


$$f_2 = \frac{V_2 \times 15{,}5^2\, \tfrac{1}{2} \times 1 \times 10^{-6}}{2{,}595 \times 10^{-4}} = 0{,}463\, V_2$$

$$f_1 - f_2 = \frac{V_2 \times 23 \times 1 \times 15{,}5}{2{,}595} \times 10^{-2} \Rightarrow f_1 = 1{,}857\, V_2$$

$$f_3 - f_1 = \frac{V_2 \times 15{,}5^2\, \tfrac{1}{2} \times 5}{2{,}595} \times 10^{-2} \Rightarrow f_3 = 4{,}172\, V_2$$

$$\Delta M = 0 \Rightarrow \Delta M_p + f_4 \times \Delta M_c = \frac{1}{G} \oint \frac{f_P}{e}\, ds + \frac{f_4}{G} \oint \frac{f_c}{e}\, ds \Leftarrow \text{eq. compatibilidade}$$



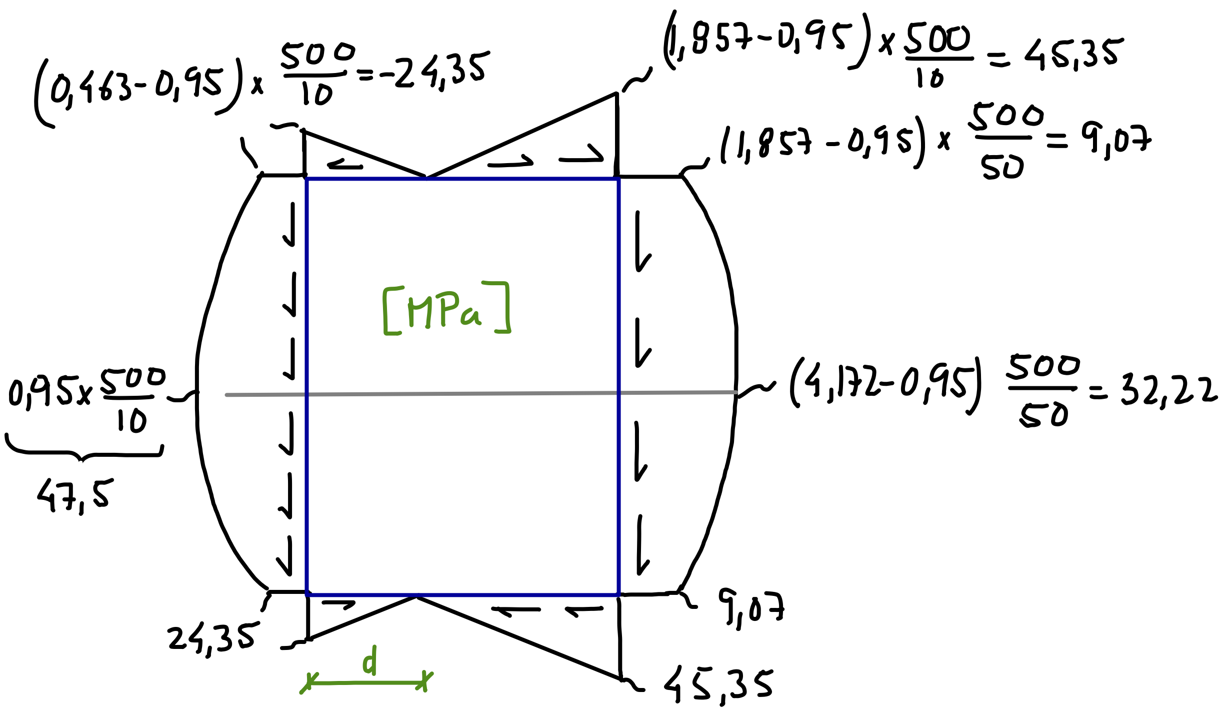
$$G \cdot \Delta M_p = 2 \times \frac{0{,}463 V_2}{0{,}01} \times \frac{1}{3} \times 0{,}155 + 2 \times \frac{\frac{1}{2}(1{,}857 + 0{,}463) V_2 \times 0{,}23}{0{,}01} + \frac{V_2}{0{,}05} \times 0{,}31 \left[1{,}857 + \frac{2}{3}(4{,}172 - 1{,}857)\right]$$

$$= V_2\,(4{,}63 + 53{,}36 + 21{,}08) = 79{,}07\, V_2$$

$$G \cdot \Delta M_c = \frac{0{,}31}{0{,}01} + 2 \times \frac{0{,}23}{0{,}01} + \frac{0{,}31}{0{,}05} = 83{,}2$$

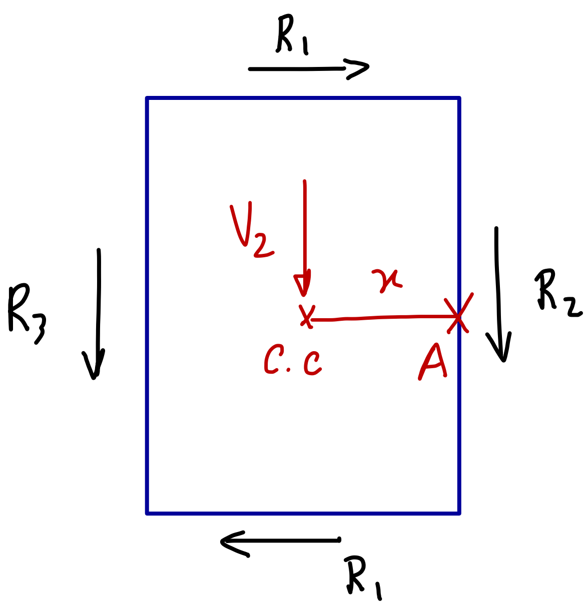
$$\Delta M_p + f_4 \times \Delta M_c = 0 \Rightarrow f_4 = -\frac{79{,}07 V_2}{83{,}2} = -0{,}95\, V_2$$

V_2



$$\left.\begin{array}{l} d \;—\; 45{,}35 \\ 23 \;—\; 24{,}35 + 45{,}35 \end{array}\right\} \Rightarrow d = 8{,}035 \text{ cm}$$

b) Determine a posição do centro de corte da secção.



$$R_1 = e \int \left(\triangle_{45,35}^{\,23-d} - \triangle_{24,35}^{\,d} \right) ds$$

$$R_1 = 10 \times \frac{1}{2} \left[-24{,}35\, d + 45{,}35\,(23-d) \right] \times 10/1000 =$$

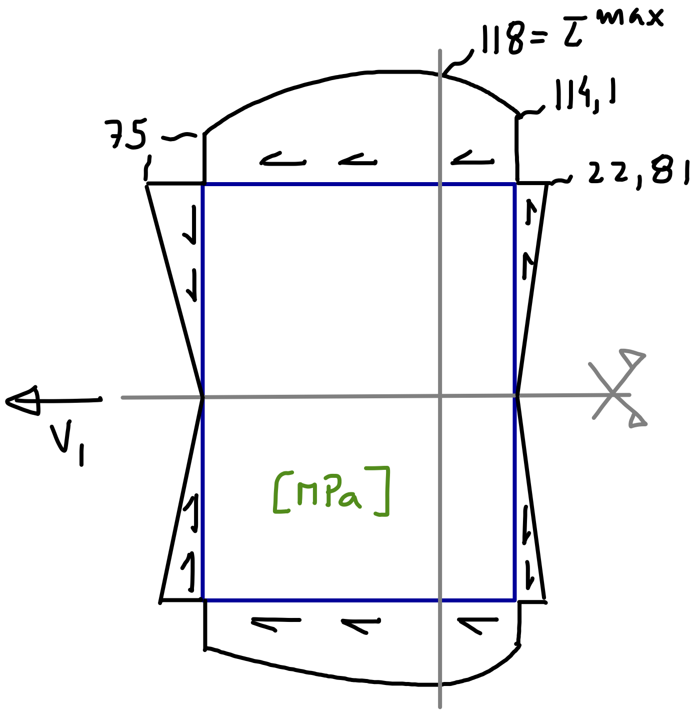
$$= 24{,}15 \text{ kN}$$

$$R_3 = e \int \left(\square_{24,35}^{\,31} + \frown_{47,5-24,35}^{\,31} \right) ds$$

$$R_3 = 10 \times 310 \left[24{,}35 + \frac{2}{3}(47{,}5 - 24{,}35) \right] / 1000 = 123{,}3 \text{ kN}$$

$$\Sigma M_A \rightarrow 123 \times 23 - 24{,}15 \times 31 = x \times 500 \Rightarrow x = 4{,}161 \text{ cm}$$

c) Calcule a área de corte segundo a direcção 1.



$$A^*_{V1} = \frac{V_1^2}{\int_\Omega \tau_1^2 \, d\Omega}$$

$118-75=43$ $\quad$ $118-114{,}1=3{,}9$

$$\int_\Omega \tau_1^2 \, d\Omega = 2 \times \int \left(\overset{75}{\underset{15,5}{}} \right)^2 + 5 \times \left(\overset{22,81}{\underset{15,5}{}} \right)^2 + \left(\overset{75}{\underset{17,647}{}} + \overset{43}{} \right)^2 + \left(\overset{114,1}{\underset{5,353}{}} + \overset{3,9}{} \right)^2 ds$$

$$= 2\left[\frac{1}{3} 75^2 \times 15{,}5 + \frac{5}{3} 22{,}81^2 \times 15{,}5 + 17{,}647 \times \left(75^2 + 2\,\frac{2}{3}\,75 \times 43 + \frac{8}{15}\,43^2\right) + 5{,}353 \times \left(114{,}1^2 + 2 \times \frac{2}{3}\,114{,}1 \times 3{,}9 + \frac{8}{15}\,3{,}9^2\right)\right]$$

$$= 61833 \ kN^2/cm^2$$

$$A^*_{V1} = \frac{500^2}{6183{,}3} = 40{,}43 \ cm^2$$