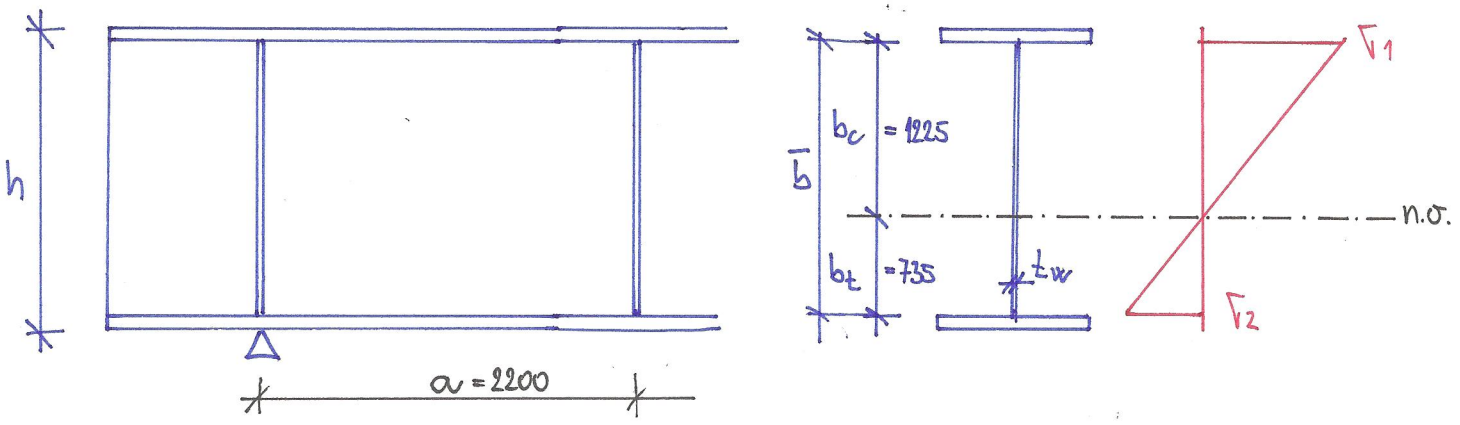
BOULENÍ STOJINY HLAVNÍHO NOSNÍKU VLIVEM TLAKU OD OHYBU

a) Bez podélné výztuhy stojiny hl. nosníku

$t_f = 20\,mm$; $h = 2000\,mm$; $t_w = 4\,mm$



$$\psi = \frac{\sigma_2}{\sigma_1} = \frac{-735}{1225} = -0{,}16 \quad ; \quad \varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{355}} = 0{,}81$$

$$k_\sigma = 7{,}81 - 6{,}29 \cdot \psi + 9{,}78 \cdot \psi^2 = 7{,}81 - 6{,}29 \cdot (-0{,}16) + 9{,}78 \cdot (-0{,}16)^2 = 8{,}06$$

$$\rho = \frac{\bar{\lambda}_p - 0{,}055 \cdot (3+\psi)}{\bar{\lambda}_p^2} = \frac{7{,}50 - 0{,}055 \cdot (3+(-0{,}16))}{7{,}5^2} = 0{,}131 \quad *$$

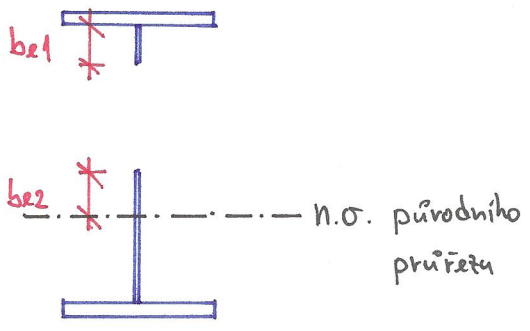
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28{,}4 \cdot \varepsilon \cdot \sqrt{k_\sigma}} = \frac{1960/4}{28{,}4 \cdot 0{,}81 \cdot \sqrt{8{,}06}} = 7{,}50$$

* pro $\bar{\lambda}_p > 0{,}5 + \sqrt{0{,}085 - 0{,}055 \cdot \psi} = 0{,}84$

$$b_{eff} = \rho \cdot b_c = \rho \cdot \bar{b} / (1-\psi) = 0{,}131 \cdot 1960 = 160\,mm$$

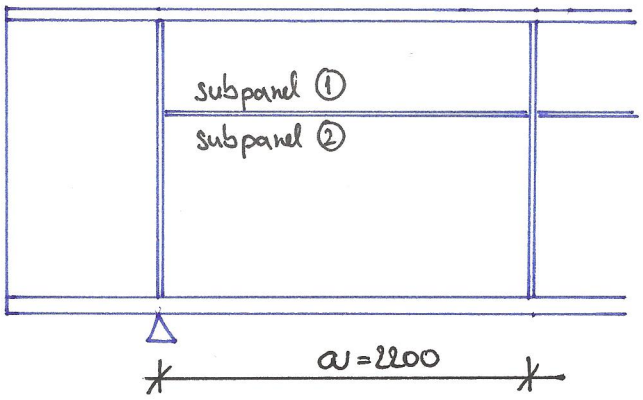
$b_{e1} = 0{,}4\ b_{eff} = 0{,}4 \cdot 160 = 64\,mm$

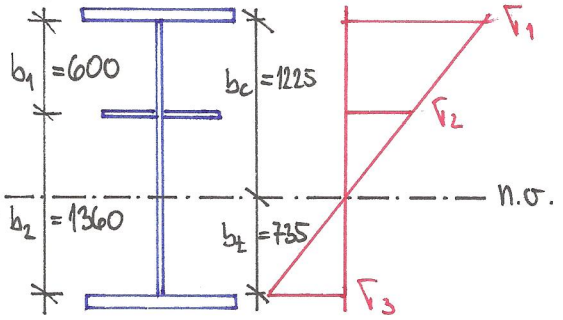
$b_{e2} = 0{,}6\ b_{eff} = 0{,}6 \cdot 160 = 96\,mm$



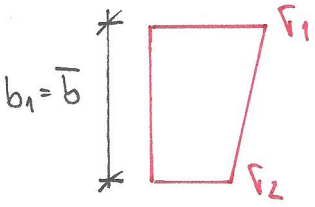
b) Podélná výztuha stojiny hl. nosníku

- podélná výztuha se umístí přibližně do středu neúčinné části z příkladu a)





- Subpanel ① - celý tlačený



$$\psi = \frac{\sigma_2}{\sigma_1} = \frac{b_1}{b_c} = \frac{600}{1225} = 0{,}49$$

$$k_\sigma = 8{,}2/(1{,}05+\psi) = 8{,}2/(1{,}05+0{,}49) = 5{,}32$$

$$\bar{\lambda}_p = \frac{\bar{b}/t}{28{,}4\cdot\varepsilon\cdot\sqrt{k_\sigma}} = \frac{600/4}{28{,}4\cdot 0{,}81\cdot\sqrt{5{,}32}} = 2{,}83$$

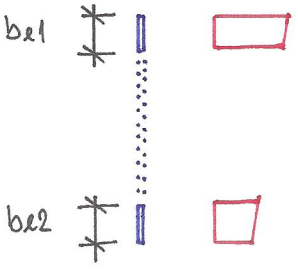
$$\rho = \frac{\bar{\lambda}_p - 0{,}055\cdot(3+\psi)}{\bar{\lambda}_p^2} = \frac{2{,}83 - 0{,}055\cdot(3+0{,}49)}{2{,}83^2} = 0{,}33$$

pro $\bar{\lambda}_p > 0{,}5 + \sqrt{0{,}085 - 0{,}055\cdot\psi} = 0{,}74$

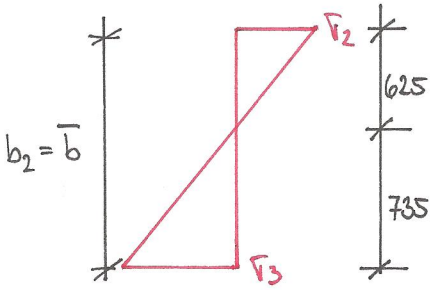
$$b_{eff} = \rho\cdot\bar{b} = 0{,}33\cdot 600 = 198 \text{ mm}$$

$$b_{e1} = \frac{2}{5-\psi}\cdot b_{eff} = \frac{2}{5-0{,}49}\cdot 198 = 88 \text{ mm}$$

$$b_{e2} = b_{eff} - b_{e1} = 198 - 88 = 110 \text{ mm}$$



- Subpanel ② – částečně tlačený



$$\psi = \frac{\sigma_3}{\sigma_2} = \frac{-735}{625} = -1{,}176$$

$$k_\sigma = 5{,}98 \cdot (1-\psi)^2 = 5{,}98 \cdot (1-(-1{,}176))^2 = 28{,}32$$

$$\bar{\lambda}_p = \frac{\bar{b}/t}{28{,}4 \cdot \varepsilon \cdot \sqrt{k_\sigma}} = \frac{1360/4}{28{,}4 \cdot 0{,}81 \cdot \sqrt{28{,}32}} = 2{,}78$$

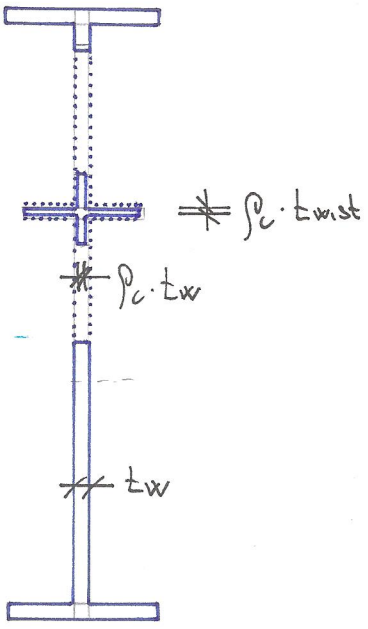
$$\rho = \frac{\bar{\lambda}_p - 0{,}055 \cdot (3+\psi)}{\bar{\lambda}_p^2} = \frac{2{,}78 - 0{,}055\,(3-1{,}176)}{2{,}78^2} = 0{,}35$$

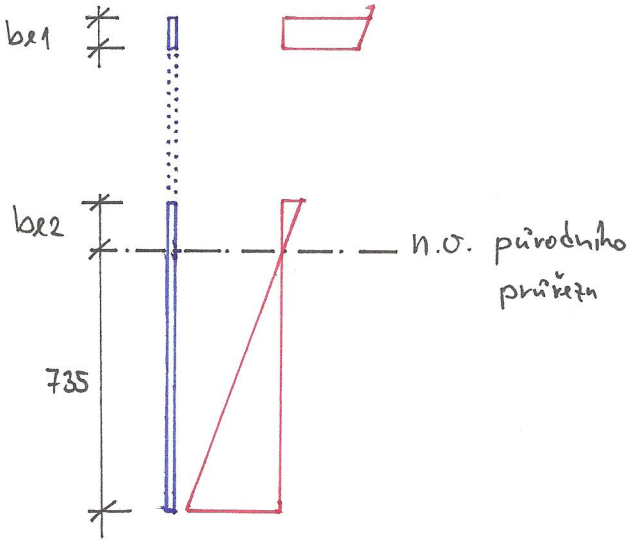
pro $\bar{\lambda}_p > 0{,}5 + \sqrt{0{,}085 - 0{,}055 \cdot \psi} = 0{,}89$

$$b_{eff} = \rho \cdot \bar{b}/(1-\psi) = 0{,}35 \cdot 1360/(1-(-1{,}176)) = 219 \text{ mm}$$

$$b_{e1} = 0{,}4 \cdot b_{eff} = 0{,}4 \cdot 219 = 88 \text{ mm}$$

$$b_{e2} = 0{,}6\ b_{eff} = 0{,}6 \cdot 219 = 131 \text{ mm}$$

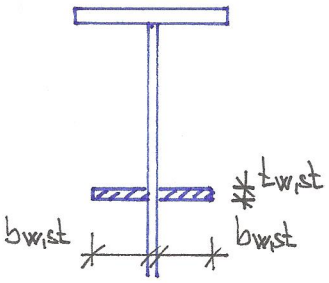




ρ_c – součinitel celkového boulení

- Ověření náhrdu podélných výztuh

má být splněno $\frac{I_t}{I_p} \geq 5{,}3 \cdot \frac{t_y}{E}$



$b_{w,st} = 180$ mm

$t_{w,st} = 20$ mm

polární moment setrvačnosti výztuhy k okraji připojeném ke stěně

$$I_p = I_y + I_z = \frac{1}{12} \cdot b_{w,st} \cdot t_{w,st}^3 + \frac{1}{12} \cdot t_{w,st} \cdot b_{w,st}^3 + b_{w,st} \cdot t_{w,st} \cdot \left(\frac{b_{w,st}}{2}\right)^2 =$$

$$= \frac{1}{12} \cdot 180 \cdot 20^3 + \frac{1}{12} \cdot 20 \cdot 180^3 + 180 \cdot 20 \cdot 90^2 = 39 \cdot 10^6 \text{ mm}^4$$

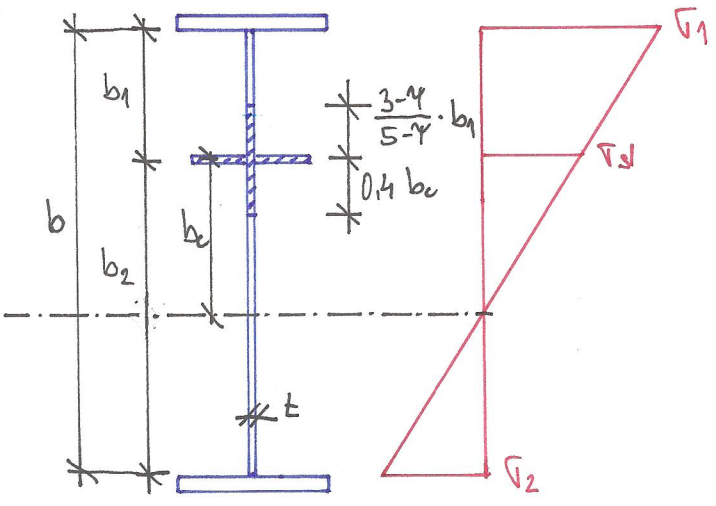
moment tuhosti v prostém kroucení

$$I_t = \frac{1}{3} \cdot b_{w,st} \cdot t_{w,st}^3 = \frac{1}{3} \cdot 180 \cdot 20^3 = 0{,}48 \cdot 10^6 \text{ mm}^4$$

$$\frac{0{,}48 \cdot 10^6}{39 \cdot 10^6} = 0{,}0123 \geq 5{,}3 \cdot \frac{355}{210 \cdot 10^3} = 0{,}00896$$ podmínka je splněna

- Součinitel celkového boulení

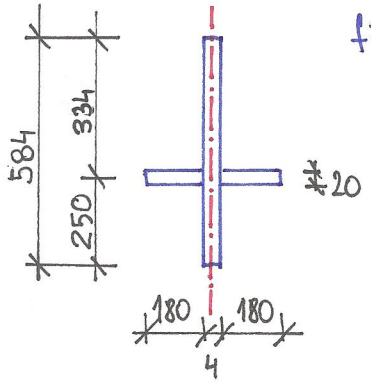
▲ stěnové chování



$$\psi = \frac{\sigma_{sl}}{\sigma_1} = \frac{600}{1225} = 0{,}49 \quad (\text{viz } ①)$$

$0{,}4 \cdot b_c = 0{,}4 \cdot 625 = 250$ mm

$\frac{3-\psi}{5-\psi} \cdot b_1 = \frac{3-0{,}49}{5-0{,}49} \cdot 600 = 334$ mm



fiktivní prut : $A_{sl,1} = 584 \cdot 4 + 2 \cdot 180 \cdot 20 = 9536\ mm^2$

$$I_{sl,1} = \frac{1}{12} \cdot 584 \cdot 4^3 + 2 \cdot \left[\frac{1}{12} \cdot 20 \cdot 180^3 + 20 \cdot 180 \cdot 92^2 \right] = 80{,}38 \cdot 10^6\ mm^4$$

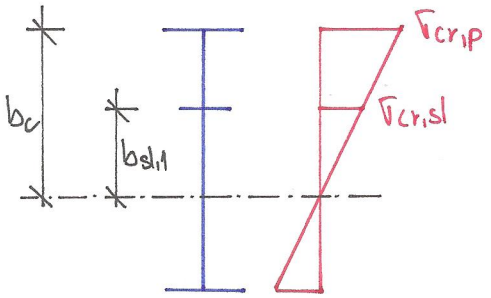
$$a_c = 4{,}33 \cdot \sqrt[4]{\frac{I_{sl,1} \cdot b_1^2 \cdot b_2^2}{t^3 \cdot b}} = 4{,}33 \cdot \sqrt[4]{\frac{80{,}38 \cdot 10^6 \cdot 600^2 \cdot 1360^2}{4^3 \cdot 1960}} = 19\,679\ mm$$

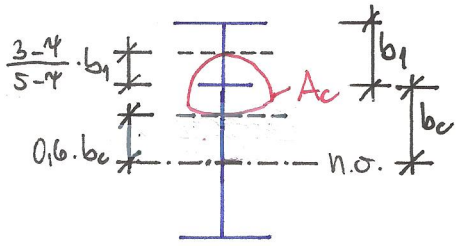
pro $a = 2200\ mm < a_c = 19679\ mm$

$$\sigma_{cr,sl} = \frac{\pi^2 E I_{sl,1}}{A_{sl,1} \cdot a^2} + \frac{E \cdot t^3 \cdot b \cdot a^2}{4\pi^2 (1-\nu^2) \cdot A_{sl,1} \cdot b_1^2 \cdot b_2^2} =$$

$$= \frac{\pi^2 \cdot 210 \cdot 10^3 \cdot 80{,}38 \cdot 10^6}{9536 \cdot 2200^2} + \frac{210 \cdot 10^3 \cdot 4^3 \cdot 1960 \cdot 2200^2}{4 \cdot \pi^2 (1-0{,}3^2) \cdot 9536 \cdot 600^2 \cdot 1360^2} = 3610\ MPa$$

$$\sigma_{cr,p} = \sigma_{cr,sl} \cdot \frac{b_c}{b_{sl,1}} = 3610 \cdot \frac{1225}{625} = 7076\ MPa$$

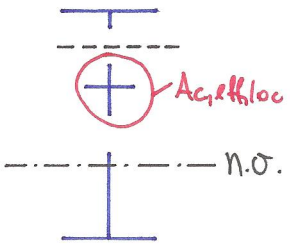




$$\beta_{A,c} = \frac{A_{c,eff,loc}}{A_c} = \frac{7992}{9536} = 0{,}840$$

$$A_c = 4 \cdot (334 + 250) + 2 \cdot 180 \cdot 20 = 9536\ mm^2$$

$$A_{c,eff,loc} = 4 \cdot (88 + 110) + 2 \cdot 180 \cdot 20 = 7992\ mm^2$$



$$\bar{\lambda}_p = \sqrt{\frac{\beta_{A,c} \cdot f_y}{\sigma_{cr,p}}} = \sqrt{\frac{0840 \cdot 355}{7076}} = 0{,}205$$

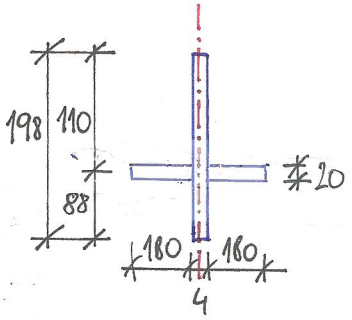
$\rho = 1{,}0$ pro $\bar{\lambda}_p \leq 0{,}673$

▲ prutové chování

$$\sigma_{cr,c} = \frac{\pi^2 \cdot E \cdot I_{sl,1}}{A_{sl,1} \cdot a^2} \cdot \frac{b_c}{b_{sl,1}} = \frac{\pi^2 \cdot 210.10^3 \cdot 80{,}38.10^6}{9536 \cdot 2200^2} \cdot \frac{1225}{625} = 7075 \text{ MPa}$$

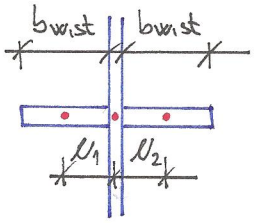
$$\beta_{A,c} = \frac{A_{sl,1,eff}}{A_{sl,1}} = \frac{7992}{9536} = 0{,}84$$

$$A_{sl,1,eff} = 198 \cdot 4 + 2 \cdot (180 \cdot 20) = 7992 \text{ mm}^2$$



$$\bar{\lambda}_c = \sqrt{\frac{\beta_{A,c} \cdot f_y}{\sigma_{cr,c}}} = \sqrt{\frac{0{,}84 \cdot 355}{7075}} = 0{,}205$$

$$i = \sqrt{\frac{I_{sl,1}}{A_{sl,1}}} = \sqrt{\frac{80{,}38.10^6}{9536}} = 91{,}8 \text{ mm}$$



$l = 92$ mm $\qquad l = \max\{l_1 ; l_2\}$

$$\alpha_e = \alpha + \frac{0{,}09}{\frac{i}{l}} = 0{,}49 + \frac{0{,}09}{\frac{91{,}8}{92}} = 0{,}58$$

$$\phi = 0{,}5\left[1 + \alpha_e \cdot (\bar{\lambda}_c - 0{,}2) + \bar{\lambda}_c^2\right] = 0{,}5\left[1 + 0{,}58 \cdot (0{,}205 - 0{,}2) + 0{,}205^2\right] = 0{,}52$$

$$\chi_c = \frac{1}{\phi + \sqrt{\phi^2 - \bar{\lambda}_c^2}} = \frac{1}{0{,}52 + \sqrt{0{,}52^2 - 0{,}205^2}} = 0{,}99$$

▲ interakce mezi stěnovým a prutovým chováním

$$\xi = \frac{\sigma_{cr,p}}{\sigma_{cr,c}} - 1 = \frac{7076}{7075} - 1 = 0{,}00014$$

$$\rho_c = (\rho - \chi_c) \cdot \xi \cdot (2 - \xi) + \chi_c = (1 - 0{,}99) \cdot 0{,}00014 \cdot (2 - 0{,}00014) + 0{,}99 = 0{,}99$$