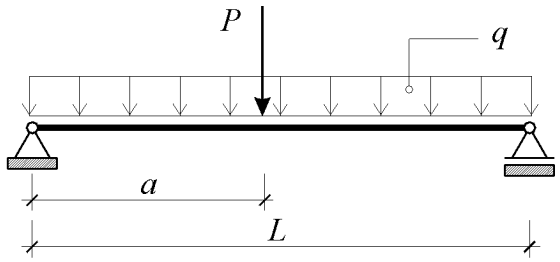
10. Zadatak

Dimenzionisati podni nosač sistema proste grede koji je opterećen zadatim opterećenjem. Nosač je kontinualno bočno pridržan. Sračunati i konstruisati zglobnu vezu podnog nosača sa:
- stubom
- podvlakom.

Vezu ostvariti pomoću:
- priključnog lima,
- priključnog ugaonika,
- stolice
- čeone ploče.

Za vezu se primenjuju:
- neobrađeni zavrtnjevi klase čvrstoće 4.6 5.6 6.8
- obrađeni zavrtnjevi klase čvrstoće 4.6 5.6 6.8
- visokovredni zavrtnjevi bez sile pritezanja, klase čvrstoće 8.8 10.9



q = 15 kN/m

P = 120 kN

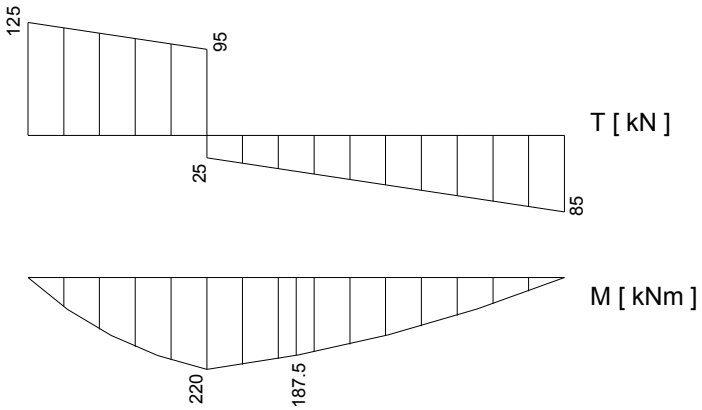
a = 2 m

L = 6 m

Osnovni materijal: Č0361
Slučaj opterećenja: I
Radionički crtež dati u razmeri: 1:5
Napomena: pri cratanju, dimenzije stuba odnosno podvlake usvojiti proizvoljno.

Osnovni materijal Č0361: σ_{dop}= 16,0 kN/cm^2 τ_{dop}= 9,0 kN/cm^2
Neobrađeni zavrtnjevi klase 5.6: σ_{bdop}= 27,0 kN/cm^2 τ_{dop}= 14,0 kN/cm^2
Ugaoni šavovi: $\sigma_{w,dop}$= 12,0 kN/cm^2

1. Statički uticaji u nosaču



2. Dimenzionisanje nosača

$$W_{pot} = \frac{M_{\max}}{\sigma_{dop}} = \frac{22000}{16} = 1375\,\text{cm}^3$$

Usvaja se valjani profil **IPE 450** sa geometrijskim karakteristikama:
h = 450 mm b_f = 190 mm t_f = 14,6 mm t_w = 9,4 mm r = 21 mm
d = 42,08 cm I_y = 33740 cm^4 W_y = 1500 cm^3 S_y = 851 cm^3

2.1 Kontrola napona

Presek nad osloncem (T_{max} = 125,0 kNm)

$$\tau = \frac{V \cdot S_x}{I_x \cdot t_w} = \frac{125 \cdot 851}{33740 \cdot 0{,}94} = 3{,}35\,\text{kN/cm}^2 < \tau_{\text{dop}} = 9{,}0\,\text{kN/cm}^2$$

Presek u polju (M = 220,0 kNm; T_{odg} = 95,0 kN)

$$\sigma = \frac{22000}{1500} = 14{,}67\,\text{kN/cm}^2 < \sigma_{dop} = 16{,}0\,\text{kN/cm}^2$$

$$\sigma_1 = \frac{M}{I} \cdot d/2 = \frac{22000}{33740} \cdot 42{,}08/2 = 13{,}72\,\text{kN/cm}^2$$

$$S_y' = b_f \cdot t_f \cdot (h - t_f)/2 = 19 \cdot 1{,}46 \cdot (45 - 1{,}46)/2 = 603{,}9\,\text{cm}^3$$

$$\tau_1 = \frac{S_y' \cdot T_{odg}}{I_y \cdot t_w} = \frac{603{,}9 \cdot 95}{33740 \cdot 0{,}94} = 1{,}81\,\text{kN/cm}^2$$

$$\sigma_u = \sqrt{\sigma_1^2 + 3 \cdot \tau_1^2} = \sqrt{13{,}72^2 + 3 \cdot 1{,}81^2} = 14{,}07\,\text{kN/cm}^2 < \sigma_{dop} = 16{,}0\,\text{kN/cm}^2$$

2.2 Kontrola ugiba

$$f_{max}(q) = \frac{5 \cdot q \cdot l^4}{384 \cdot I_x \cdot E} = \frac{5 \cdot 0{,}15 \cdot 600^4}{384 \cdot 21000 \cdot 33740} = 0{,}36\,\text{cm}$$

$$f_{max}(P) = \frac{P}{27 \cdot E \cdot I_x} \cdot \frac{a}{l} \cdot \sqrt{3 \cdot \left(l^2 - a^2\right)^3} = \frac{120}{27 \cdot 21000 \cdot 33740} \cdot \frac{200}{600} \cdot \sqrt{3 \cdot \left(600^2 - 200^2\right)^3}$$

$f_{max}(P)$ = 0,66 cm

Položaj maksimalnog ugiba usled sile P = 120 kN

$$x = \sqrt{\frac{l^2 - a^2}{3}} = \sqrt{\frac{600^2 - 200^2}{3}} = 326\,\text{cm} \approx 300\,\text{cm} = \frac{l}{2}$$

$f_{max}(q+P)$ = 0,36 + 0,66 = 1,02 cm < 2,0 cm = l/300 = f_{dop}

3. VARIJANTA I: Proračun veza nosača i podvlake pomoću priključnog lima

Nosač je zasečen 30 mm da bi se smanjio ekscentricitet veze (h_1 = 45 - 3 = 42 cm)
Za vezu se koriste zavrtnjevi M20...5.6.
Predpostavlja se ekscentricitet veze: e = 55 mm

3.1 Kontrola napona u oslabljenom preseku (A-A)

Geometrijske karakteristike oslabljenog preseka.

$$A = t_w \cdot (h_1 - t_f) + b_f \cdot t_f = 0.94 \cdot (42 - 1.46) + 1.46 \cdot 19 = 65{,}85\,\text{cm}^2$$

Položaj težišta:

$$h_c = h_1 - \frac{h_1}{2} \cdot \frac{t_w \cdot (h_1 - t_f)}{A} - \frac{t_f}{2} = 42 - \frac{42}{2} \cdot \frac{0{,}94 \cdot (42 - 1{,}46)}{65{,}85} - \frac{1{,}46}{2} = 29{,}12\,\text{cm}$$

$$I_y = \frac{t_w \cdot (h_1 - t_f)^3}{12} + \frac{b_f \cdot t_f \cdot t_w \cdot (h_1 - t_f)}{A} \cdot \left(\frac{h_1}{2}\right)^2$$

$$I_y = \frac{0{,}94 \cdot (42 - 1{,}46)^3}{12} + \frac{19 \cdot 1{,}46 \cdot 0{,}94 \cdot (42 - 1{,}46)}{65.85} \cdot \left(\frac{42}{2}\right)^2 = 12299 \text{ cm}^4$$

$$W_y = \frac{I_y}{h_c} = \frac{12299}{29{,}12} = 422{,}4 \text{ cm}^3$$

Ekscentricitet najudaljenijeg oslabljenog preseka e = 18,0 cm (videti crtež).

$$\sigma = \frac{M_e}{W_{y,\min}} = \frac{V \cdot e}{W_{y,\min}} = \frac{125 \cdot 18}{422{,}4} = 5{,}33 \text{ kN/cm}^2 < \sigma_{dop} = 16{,}0 \text{ kN/cm}^2$$

$$\tau = \frac{V}{t_w \cdot (h_1 - t_f)} = \frac{125}{0{,}94 \cdot (42 - 1{,}46)} = 3{,}28 \text{ kN/cm}^2 < \tau_{dop} = 9{,}0 \text{ kN/cm}^2$$

$$\sigma_u = \sqrt{\sigma^2 + 3 \cdot \tau^2} = \sqrt{5{,}33^2 + 3 \cdot 3{,}28^2} = 7{,}79 \text{ kN/cm}^2 < \sigma_{dop} = 16{,}0 \text{ kN/cm}^2$$

3.2 Veza priključnog lima za rebro podvlake

Predpostavlja se priključni lim = 105 x 15 x 360
Pretpostavljaju se minimalni šavovi za vezu a_w = 3 mm; ($l_w = h_p$ =360 mm)

$$M_T = \frac{V \cdot (t_p + t_w)}{2} = \frac{125 \cdot (1{,}5 + 0{,}94)}{2} = 152{,}5 \text{ kNcm}$$

$$M_e = 125 \cdot 5{,}5 = 687{,}5 \text{ kNcm}$$

$$n = \frac{M_e}{W_w} = \frac{M_e}{2 \cdot \frac{a_w \cdot l_w^2}{6}} = \frac{687{,}5 \cdot 3}{0{,}3 \cdot 36^2} = 5{,}3 \text{ kN/cm}^2$$

$$V_{II,V} = \frac{V}{A_{w,v}} = \frac{125}{2 \cdot 36 \cdot 0{,}3} = 5{,}79 \text{ kN/cm}^2$$

$$V_{II,T} = \frac{M_T}{W_{w,T}} = \frac{M_T}{2 \cdot (a + t_p) \cdot (h_p + a) \cdot a} = \frac{152{,}5}{2 \cdot (0{,}3 + 1{,}5) \cdot (36 + 0{,}3) \cdot 0{,}3} = 3{,}89 \text{ kN/cm}^2$$

$$\sigma = \sqrt{n^2 + (V_{II,V} + V_{II,T})^2} = \sqrt{5{,}3^2 + (5{,}79 + 3{,}89)^2} = 11{,}0 \text{ kN/cm}^2 < \sigma_{w,dop} = 12 \text{ kN/cm}^2$$

3.3 Kontrola napona u priključnom limu

$$\sigma_{\max} = \frac{M_e}{W_p} = \frac{V \cdot e}{t_p \cdot h_p^2 / 6} = \frac{125 \cdot 5{,}5}{1{,}5 \cdot 36^2 / 6} = 2{,}12 \text{ kN/cm}^2$$

$$\tau_V = \frac{V}{t_p \cdot h_p} = \frac{125}{1{,}5 \cdot 36} = 2{,}31 \text{ kN/cm}^2$$

$$\tau_T = \frac{M_T}{W_T} = \frac{V \cdot (t_p + t_w)/2}{h_p \cdot t_p^2 / 3} = \frac{125 \cdot (1{,}5 + 0{,}94)/2}{36 \cdot 1{,}5^2 / 3} = 5{,}65 \text{ kN/cm}^2$$

$$\sigma_u = \sqrt{\sigma^2 + 3 \cdot (\tau_V + \tau_T)^2} = \sqrt{2{,}12^2 + 3 \cdot (2{,}31 + 5{,}65)^2} = 13{,}95 \text{ kN/cm}^2 < \sigma_{dop}$$

3.4 Veza priključnog lima za rebro nosača

Proračun nosivosti zavrtnja na smicanje

$$F_V = \frac{2{,}0^2 \cdot \pi}{4} \cdot 14{,}0 = 43{,}98\,\text{kN}$$

$$F_b = 0{,}94 \cdot 2{,}0 \cdot 27{,}0 = 50{,}76\,\text{kN}$$

F_{dop}= min {43,98 ; 50,76} = 43,98 kN

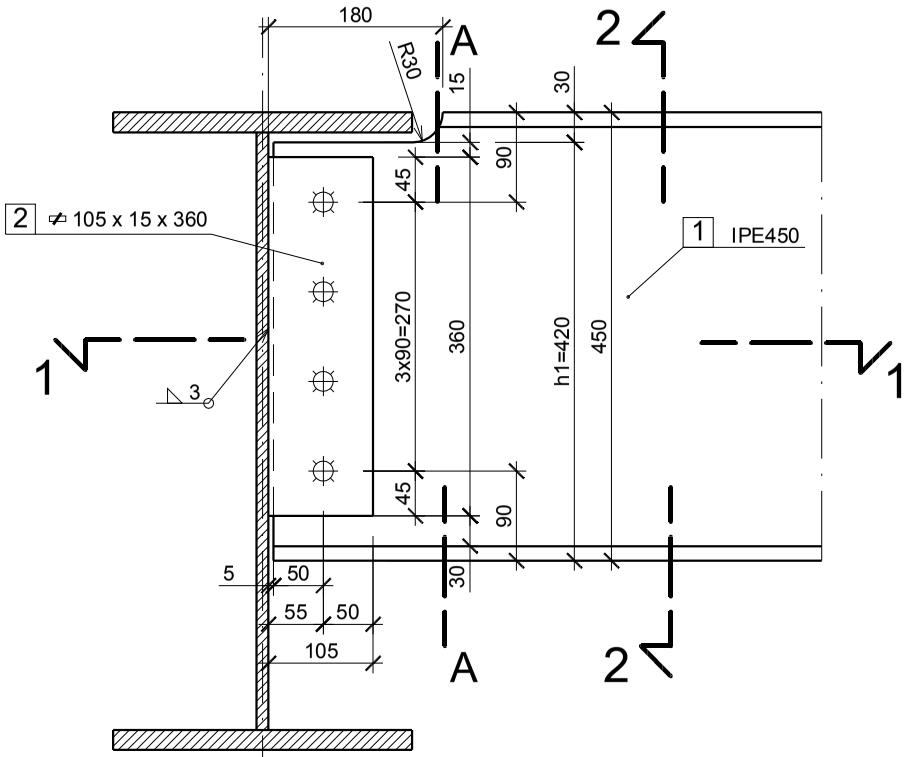
Proračun potrebnog broja zavrtnjeva

$$n = \frac{1}{F_{dop}} \cdot \sqrt{V^2 + \left(\frac{6 \cdot M_e}{h}\right)^2} = \frac{1}{43{,}98} \cdot \sqrt{125^2 + \left(\frac{6 \cdot 125 \cdot 5{,}5}{36}\right)^2} = 3{,}85 \quad \Rightarrow \quad n = 4$$

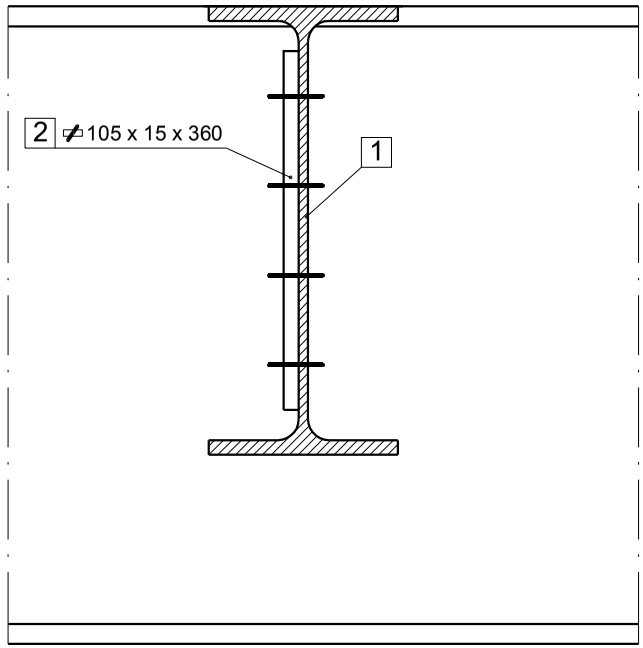
$$F_V = \frac{V}{n} = \frac{125}{4} = 31{,}25\,\text{kN}$$

$$\max F_M = \frac{M_e \cdot h_n}{\sum h_i^2} = \frac{125 \cdot 5{,}5 \cdot 27}{9^2 + 27^2} = 22{,}92\,\text{kN}$$

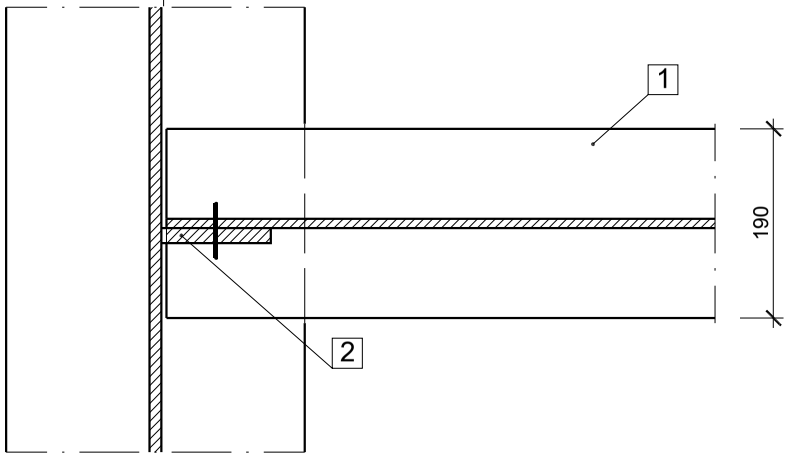
$$F_{R,\max} = \sqrt{F_V^2 + \max F_M^2} = \sqrt{31{,}25^2 + 22{,}92^2} = 38{,}75\,\text{kN} < F_{dop} = 43{,}95\,\text{kN}$$



Presek 2-2



Presek 1-1



Osnovni materijal Č0361

M20 ... 5.6

R 1:5

4. VARIJANTA II: Proračun veze nosača i podvlake pomoću priključnih ugaonika

Nosač je zasečen 30 mm da bi se smanjio ekscentricitet veze
Za vezu se koriste zavrtnjevi **M16** i ugaonici **L90x90x9** .
e = 50 mm

4.1 Kontrola napona u oslabljenom preseku

Identično kao i za VARIJANTU I

4.2 Veza rebra nosača sa priključnim ugaonicima (zavrtnjevi serije 1)

$$F_V = 2 \cdot \frac{1{,}6^2 \cdot \pi}{4} \cdot 14 = 56{,}3\ \text{kN}$$

$$F_b = 0{,}94 \cdot 1{,}6 \cdot 27 = 40{,}61\ \text{kN}$$

F_{dop}= min {56,3 ; 40,61} = 40,61 kN

Predpostavlja se n = 4

$$F_V = \frac{V}{n} = \frac{125}{4} = 31{,}25\ \text{kN}$$

$$\max F_M = \frac{M_e \cdot h_n}{\sum h_i^{\,2}} = \frac{125 \cdot 5{,}0 \cdot 27}{9^2 + 27^2} = 20{,}83\ \text{kN}$$

$$F_{R,\max} = \sqrt{F_V^{\,2} + \max F_M^{\,2}} = \sqrt{31{,}25^2 + 20{,}83^2} = 37{,}56\ \text{kN} < F_{dop} = 40{,}61\ \text{kN}$$

4.3 Kontrola napona u priključnim ugaonicima

Geometrijske karakteristike neto poprečnog preseka ugaonika. (h_p = 36 cm)
A_{net}= 2·36·0,9 - 4·1,7·0,9 = 58,68 cm^2

$$I_{net} = 2 \cdot \left[\frac{36^3 \cdot 0{,}9}{12} - 0{,}9 \cdot 1{,}7 \cdot (4{,}5^2 + 13{,}5^2) \right] = 6379\ \text{cm}^4$$

$$W_{net} = \frac{I_{net}}{h_p / 2} = \frac{6379}{18} = 354{,}4\ \text{cm}^3$$

$$\sigma = \frac{M_e}{W_{y,\min}} = \frac{V \cdot e}{W_{y,\min}} = \frac{125 \cdot 5}{354{,}4} = 1{,}76\ \text{kN/cm}^2 < \sigma_{\text{dop}}$$

$$\tau = \frac{V}{A_{net}} = \frac{125}{58{,}68} = 2{,}13\ \text{kN/cm}^2 < \tau_{dop}$$

$$\sigma_u = \sqrt{\sigma^2 + 3 \cdot \tau^2} = \sqrt{1{,}76^2 + 3 \cdot 2{,}13^2} = 4{,}09\ \text{kN/cm}^2 < \sigma_{\text{dop}}$$

4.4 Veza priključnog ugaonika za rebro podvlake

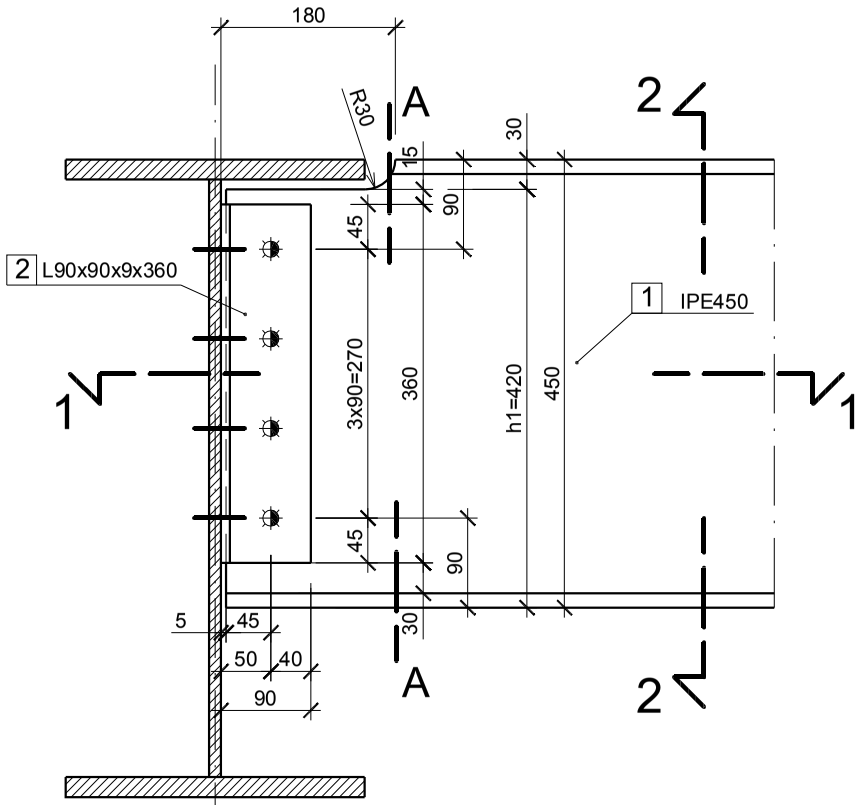
Za vezu se predpostavljaju zavrtnjevi 2x4=8M16...6.8.

$$F_V = \frac{1{,}6^2 \cdot \pi}{4} \cdot 14 = 28{,}15\ \text{kN}$$

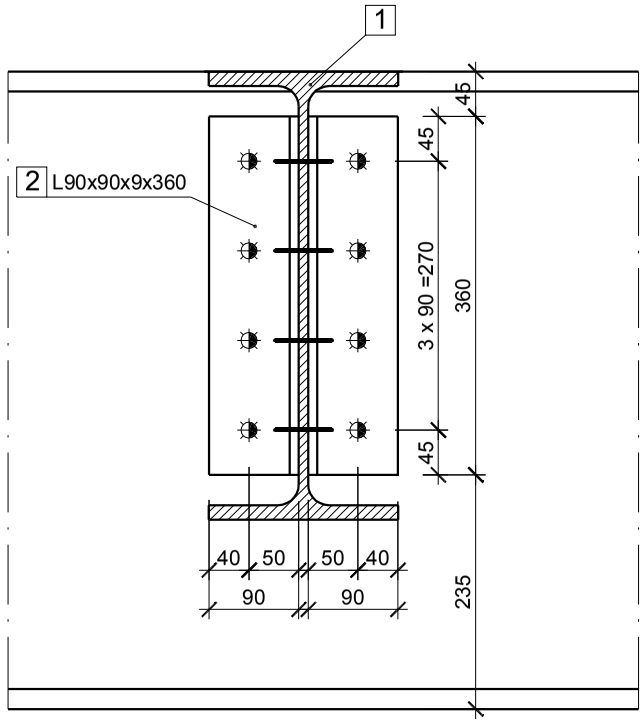
F_{dop}= min {28,15 ; 38,88} = 28,15 kN

$$F_b = 0{,}9 \cdot 1{,}6 \cdot 27 = 38{,}88\ \text{kN}$$

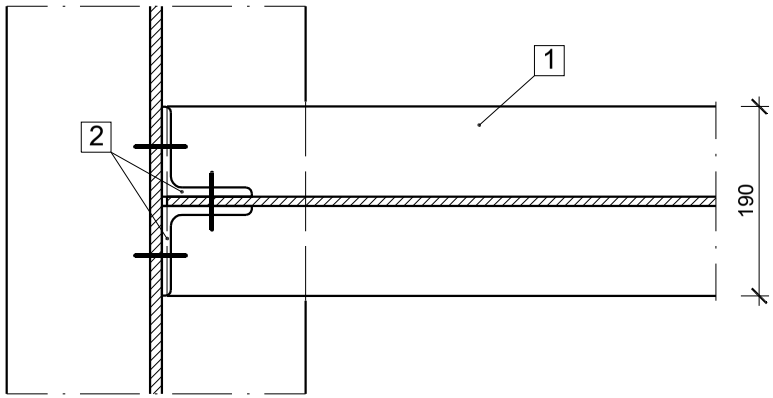
$$F_v = \frac{V}{2 \cdot n} = \frac{125}{2 \cdot 4} = 15{,}62\ \text{kN} < F_{dop} = 28{,}15\ \text{kN}$$



Presek 2-2



Presek 1-1



Osnovni materijal Č0361

M16 ... 5.6

R 1:5

5. VARIJANTA III: Proračun veze nosača i stuba pomoću čeone ploče

5.1 Proračun zavrtnjeva

Za vezu između stuba i čeone ploče koristiće se zavrtnjevi M20...5.6**.**

$$F_V = \frac{2{,}0^2 \cdot \pi}{4} \cdot 14 = 43{,}98\,\text{kN}$$

$$F_b = 1{,}5 \cdot 2{,}0 \cdot 27 = 81{,}0\,\text{kN}$$

F_{dop}= min {43,98 ; 81,0} = 43,98 kN

$$n = \frac{125}{43{,}98} = 2{,}84$$

Usvaja se 4M20...5.6

5.2 Proračun veze čeone ploče sa nosačem

Usvaja se čeona ploča = 200 x 15 mm

Potrebna visina čeone ploče iz uslova konstruisanja veze

$$h_p \geq 4 \cdot d_0 + 3 \cdot d_0 \cdot (n_1 - 1) = 4 \cdot 21 + 3 \cdot 21 \cdot (2 - 1) = 147\,\text{mm}$$

Potrebna visina čeone ploče prema smičućim naponima u rebru nosača

$$h_p \geq \frac{V}{\tau_{dop} \cdot t_w} = \frac{125}{9{,}0 \cdot 0{,}94} = 148\,\text{mm}$$

5.3 Veza rebra nosača za čeonu ploču

Veza će se ostvariti ugaonim šavovima a = 4 mm

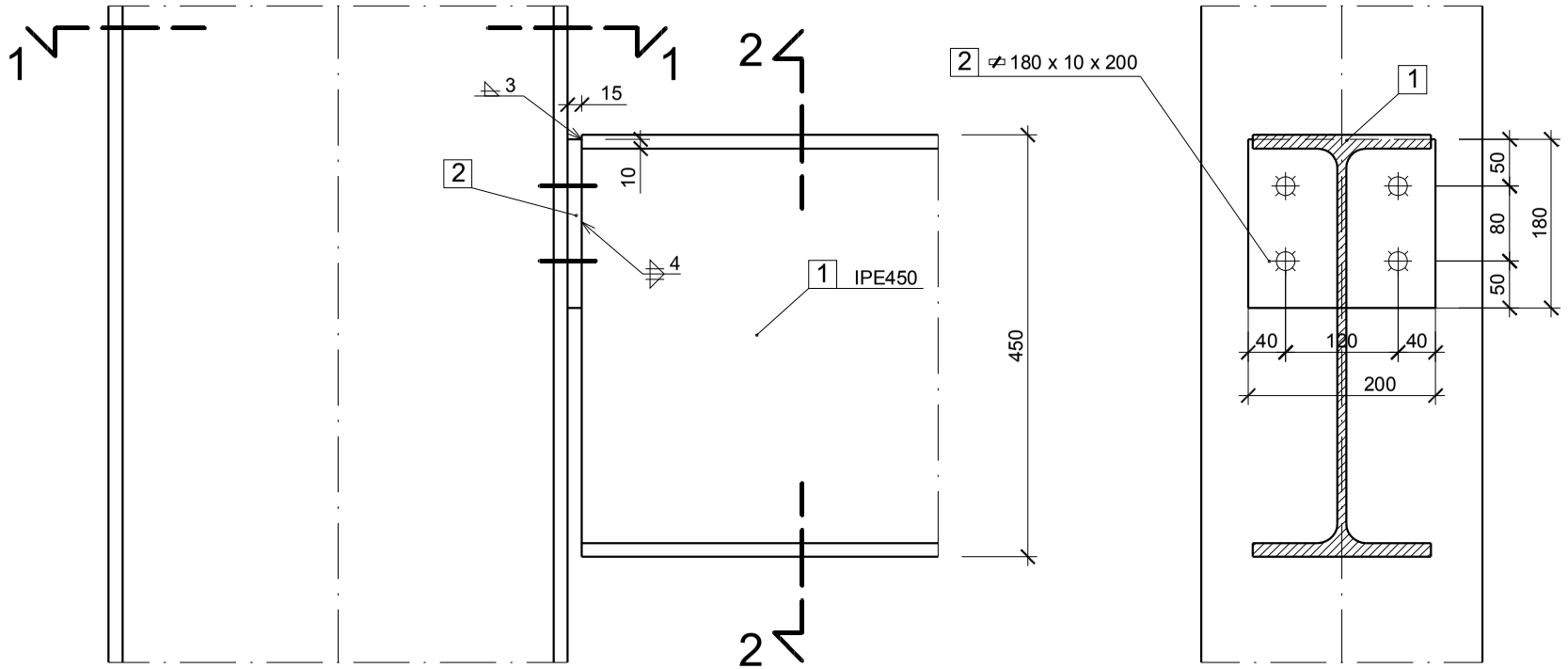
Potrebna visina čeone ploče:

$$h_p \geq \frac{V}{2 \cdot a \cdot \sigma_{w,dop}} = \frac{125}{2 \cdot 0{,}4 \cdot 12} = 130\,\text{mm}$$

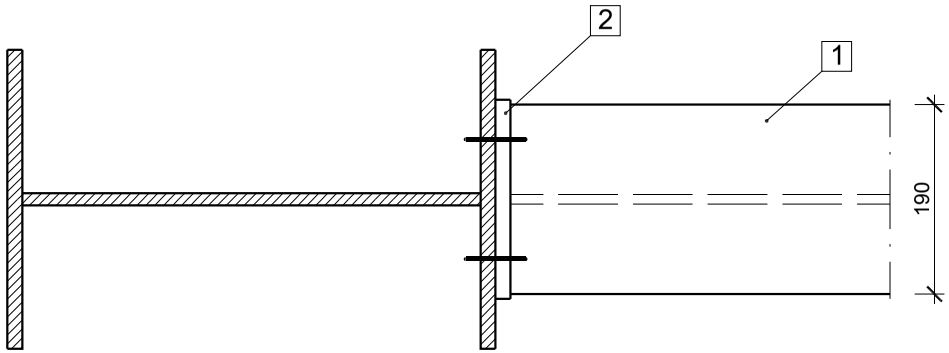
h_p > 148 mm + r + 10 mm = 148 + 21 + 10 = 179 mm

Usvaja se čeona ploča = 180 x 10 x 200

Presek 2-2



Presek 1-1



Osnovni materijal Č0361

M20 ... 5.6

R 1:5

6. VARIJANTA IV: Proračun veze nosača i stuba pomoću stolice

Predpostavlja se stolica od lima dimenzija = 150 x 40 x 200

Veza stolice za stub se ostvaruje ugaonim šavovima a_w = 4 mm po čitavom obimu.

6.1 Kontrola napona u šavovima

- vertikalni šavovi $$V_{II} = \frac{V}{2 \cdot a \cdot h} = \frac{125}{2 \cdot 0{,}4 \cdot 15} = 10{,}42 \text{ kN/cm}^2 < \sigma_{w,dop}$$

- horizontalni šavovi $$n = \frac{M_e / h}{2 \cdot a \cdot b} = \frac{125 \cdot 2{,}5 / 15}{2 \cdot 0{,}4 \cdot 20} = 1{,}30 \text{ kN/cm}^2 < \sigma_{w,dop}$$

6.2 Kontrola napona u kontaktnoj površi

$$a_{x,1} = 1{,}25 \cdot \left(t_f + r\right) = 1{,}25 \cdot \left(1{,}46 + 2{,}1\right) = 4{,}45 \text{ cm}$$

$a_{x,2} = d_c - 1{,}0 \text{ cm} = 4{,}0 - 1{,}0 = 3{,}0 \text{ cm}$

$$a_x = \min\left\{4{,}45;\quad 3{,}0\right\} = 3{,}0 \text{ cm}$$

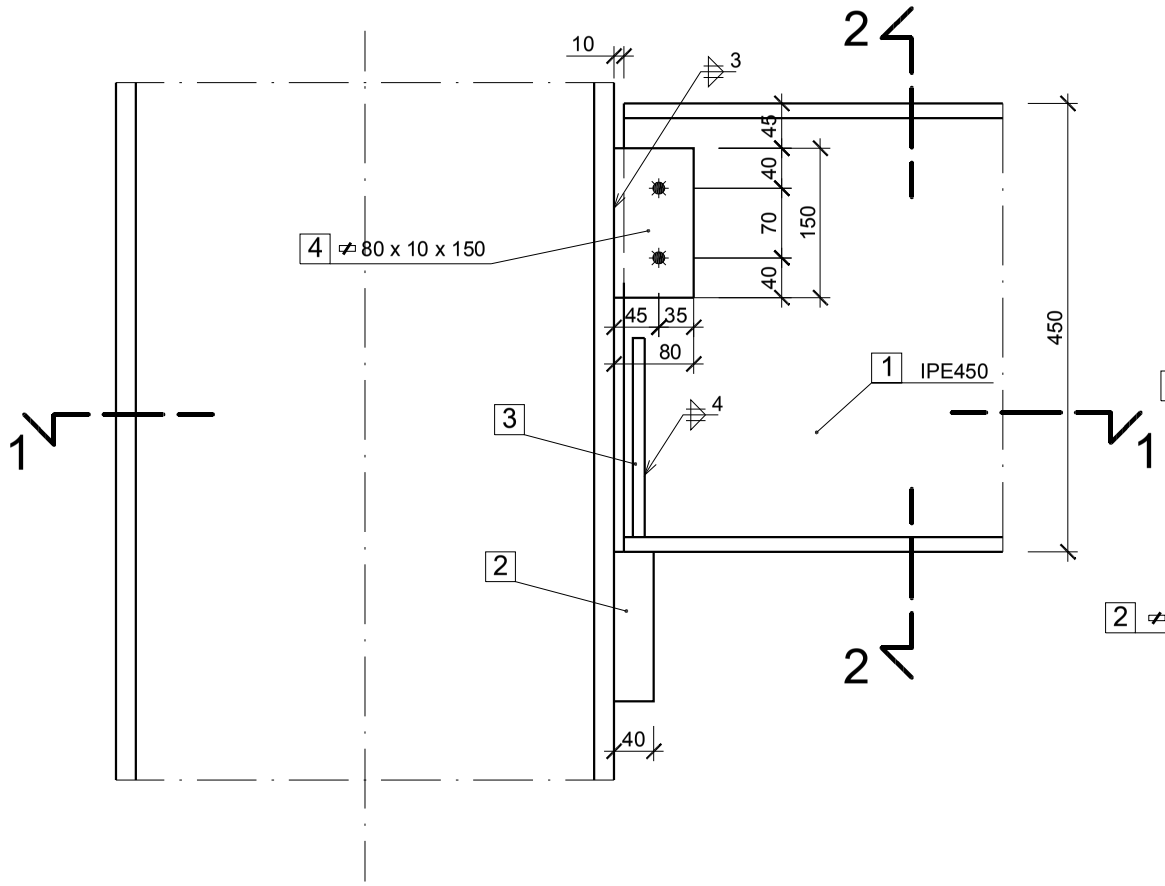
$$a_y = t_w + 1{,}46 \cdot r + 3{,}46 \cdot t_f = 0{,}94 + 1{,}46 \cdot 2{,}1 + 3{,}46 \cdot 1{,}46 = 9{,}1 \text{ cm}$$

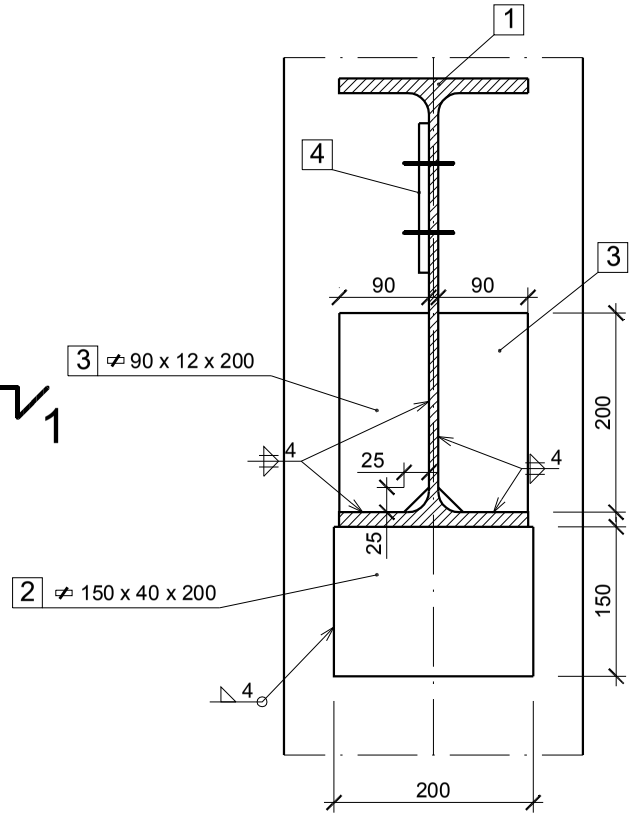
$$\sigma_c = \frac{V}{a_x \cdot a_y} = \frac{125}{3 \cdot 9{,}1} = 4{,}58 \text{ kN/cm}^2 < \sigma_{dop} = 16{,}0 \text{ kN/cm}^2$$

6.3 Kontrola napona u rebru nosača

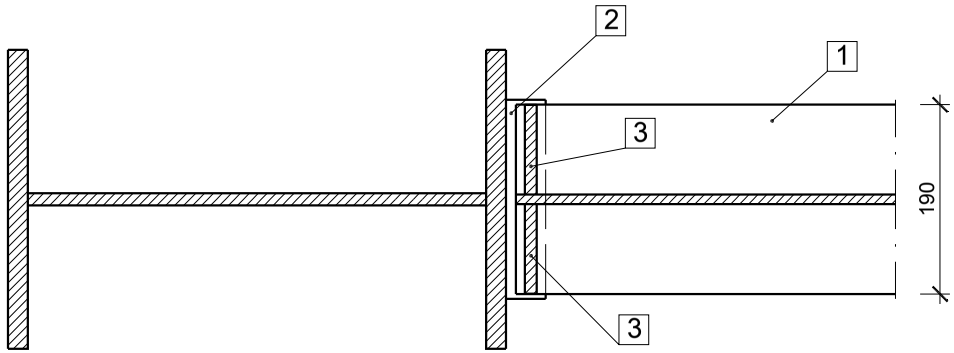
Zbog stabilnosti pritisnutog rebra u zoni oslonca potrebno je dodati ukrućenja. Usvajaju se dva ukrućenja = 90x12x200, koja se zavaruju ugaonim šavovima a_w = 4 mm (videti crtež).

Da bi se sprečilo bočno preturanje nosača predviđena je veza rebra nosača sa stubom preko priključnog lima = 80x10x150 i dva zavrtnja M12...5.6 (videti crtež).





Presek 2-2



Presek 1-1

Osnovni materijal Č0361

M12 ... 5.6

R 1:5