## 12. Zadatak

Sračunati i konstruisati nosač dizalice kao puni limeni nosač na osnovu sledećih projektnih uslova:

- statički sistem je prosta greda raspona L = 16 m
- stalno opterećenje je g = 20 kN/m
- koeficijent izravnanja $\psi$ = 1,2
- koeficijent udara $\varphi$ = 1,4
- montažni nastavak locirati tako da dužina montažnog komada ne prelazi transportnu dužinu od: $L$=12,5 m
- kontrolu stabilnosti na bočno izvijanje sprovesti sa razmakom čvorova sprega za bočne udare koja iznosi: $c = L/5$
- poprečna ukrućenja vertikalnog lima postaviti u desetinama raspona
- dopušteni ugib je: $f_{dop} = L/500$
- spojna sredstva su zavrtnjevi klase čvrstoće 10.9 sa punom silom pritezanja.
- karakteristike krana su date u tabeli

| Nosivost $Q$ | Raspon $A$ | Razmak točkova $L$ | Pritisak točka $P_1$ | | Pritisak točka $P_2$ | |
|---|---|---|---|---|---|---|
| | | | max | min | max | min |
| t | m | mm | kN | kN | kN | kN |
| 10 | 18 | 4050 | 88,9 | 32 | 96 | 39 |
| | 20 | 4050 | 90 | 34 | 99 | 41 |
| | 25 | 5000 | 99 | 43 | 113 | 48 |
| 16 | 18 | 4600 | 129 | 39 | 141 | 52 |
| | 20 | 4600 | 135 | 43 | 150 | 57 |
| | 25 | 5000 | 153 | 55 | 162 | 70 |
| 20 | 18 | 4600 | 152 | 45 | 166 | 56 |
| | 20 | 4600 | 157 | 50 | 173 | 61 |
| | 25 | 5000 | 171 | 60 | 189 | 74 |
| 32 | 18 | 5950 | 230 | 62 | 252 | 80 |
| | 20 | 5950 | 240 | 65 | 260 | 83 |
| | **25** | **5950** | **260** | **75** | **280** | **100** |

Osnovni materijal: Č0362
Slučaj opterećenja: I
Radionički crtež dati u razmeri: 1:10

### Dopušteni naponi

Osnovni materijal Č0361: $\sigma_{dop} = 16{,}0$ kN/cm$^2$ $\tau_{dop} = 9{,}0$ kN/cm$^2$
Zavrtnjevi klase čvrstoće 10.9: $f_{0,2} = 90{,}0$ kN/cm$^2$ $\nu_1 = 0{,}7$ $\nu_2 = 1{,}4$ $\mu = 0{,}5$
Ugaoni šavovi: $\sigma_{w,dop} = 12{,}0$ kN/cm$^2$



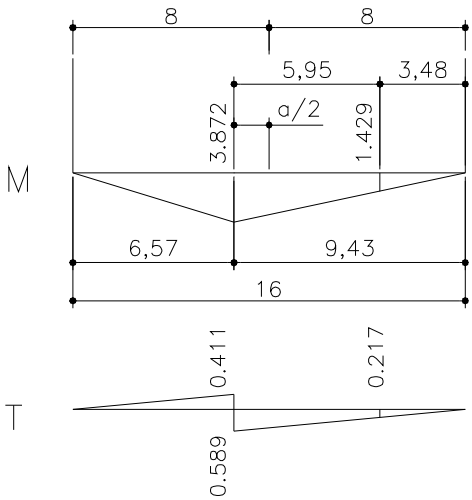
1

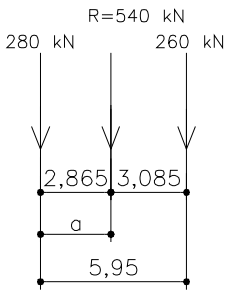
Pri izradi zadatka koriste se sledeći standardi:

1. JUS U.E7.081/1986 knjiga ČELIČNE KONSTRUKCIJE U GRAĐEVINARSTVU strane 643-649
2. JUS U.E7.101/1986 knjiga ČELIČNE KONSTRUKCIJE U GRAĐEVINARSTVU strane 674-678d
3. JUS U.E7.121/1986 knjiga ČELIČNE KONSTRUKCIJE U GRAĐEVINARSTVU strane 687-722

## 1. Maksimalni uticaji u nosaču

Na skici su prikazane karakteristične uticajne linije (na mestu maksimalnog momenta i tansverzalne sile) i šema pokretnog opterećenja.

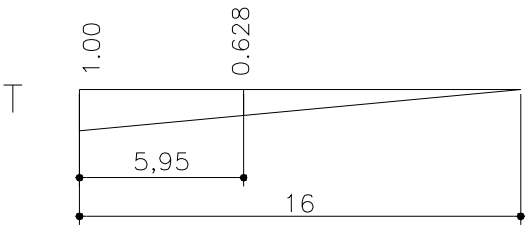



$$a = \frac{(260 \cdot 5{,}95)}{540} = 2{,}865\ \text{m}$$

$M_p$=280·3,872+260·1,429
$M_p$=1455,7 kNm
$T_p$=280·0,589+260·0,217
$T_p$=221,3 kN
$M_g$=3,872·(16/2)·20
$M_g$=619,5 kNm
$T_g$=20·16/2-6,57·20
$T_g$=28,6 kN

$M_{max}$=1,2·619,5+1,4·1455,7
**$M_{max}$= 2781,4 kNm**
$T_{odg}$=1,2·28,6 +1,4·221,3
**$T_{odg}$=344,1 kN**




$T_p$=1·280+0,628·260
$T_p$=443,3 kN
$T_g$=16·20/2=160 kN

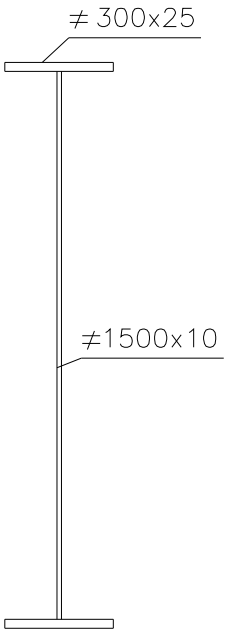
$T_{max}$=1,2·160 +1,4·443,3
**$T_{max}$ = 812,6 kN**

## 2. Oblikovanje poprečnog preseka

Visina rebra: $d$ = L/10-L/12=1,6 m -1,33 m **Usvaja se d = 1500 mm**
Debljina rebra: $t_w$= 8+2·$d$[m] = 8+2·1,5 = 11 mm **Usvaja se $t_w$= 10 mm**

$$W_{pot} = \frac{M_{\max}}{\sigma_{dop}} = \frac{278140}{16} = 17383{,}0\ \text{cm}^3$$

**Geometrijske karakteristike usvojenih poprečnih preseka:**




Poprečni presek nad osloncem:

$$I_y = \frac{150^3 \cdot 1{,}0}{12} + 2 \cdot 30 \cdot 2{,}5 \cdot \left( \frac{150 + 2{,}5}{2} \right)^2$$

$I_y$=1153359 cm$^4$

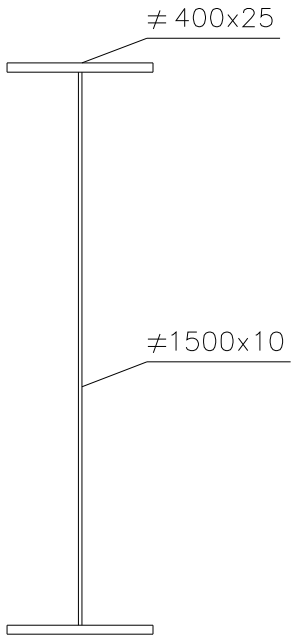
$$I_{w,y} = \frac{150^3 \cdot 1{,}0}{12} = 281250 \text{ cm}^4$$

$W_y$= 14882,1 cm$^3$

$$S_{y,0} = 30 \cdot 2{,}5 \cdot \left( \frac{150 + 2{,}5}{2} \right) = 5718{,}7 \text{ cm}^3$$

$S_y$=5718,7+150$^2$/8 = 8531,2 cm$^3$

$$M_{nos,o} = W_y \cdot \sigma_{dop} = 14882{,}1 \cdot 16 = 2381{,}1 \text{ kNm}$$




Poprečni presek u polju:

$$I_y = \frac{150^3 \cdot 1{,}0}{12} + 2 \cdot 40 \cdot 2{,}5 \cdot \left( \frac{150 + 2{,}5}{2} \right)^2$$

$I_y$=1444062,5 cm$^4$

$$I_{w,y} = \frac{150^3 \cdot 1{,}0}{12} = 281250 \text{ cm}^4$$

$W_y$= 18633,1 cm$^3$

$$S_{y,0} = 40 \cdot 2{,}5 \cdot \left( \frac{150 + 2{,}5}{2} \right) = 7625 \text{ cm}^3$$

$S_y$=7625+150$^2$/8 = 10437,5 cm$^3$

$$M_{nos} = W_y \cdot \sigma_{dop} = 18633{,}1 \cdot 16 = 2981{,}3 \text{ kNm}$$



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## 3. Određivanje teorijskog i stvarnog početka ojačanja nosača

$$M(x)=\left[\psi\cdot\frac{q\cdot l}{2}+\varphi\cdot\left[P_1+P_2\left(1-\frac{L}{l}\right)\right]\right]\cdot x-\left[\psi\cdot\frac{q}{2}+\frac{\varphi}{l}\cdot\left(P_1+P_2\right)\right]\cdot x^2$$

$$B=\left[1{,}2\cdot\frac{20\cdot 16}{2}+1{,}4\cdot\left[280+260\left(1-\frac{5{,}95}{16}\right)\right]\right]=812{,}64$$

$$A=\left[1{,}2\cdot\frac{20}{2}+\frac{1{,}4}{16}\cdot\left(280+260\right)\right]=59{,}25$$

$$A\cdot x^2-B\cdot x+M_{nos,0}=0$$

$59{,}25\cdot x^2-812{,}64\cdot x+2381{,}1=0 \qquad \Rightarrow \qquad x_T = 4{,}24$ m teorijski početak ojačanja

$$\Delta x=\frac{b}{2}=\frac{400}{2}=200=0{,}2\text{ m} \quad x_{ST}=x_T-\Delta x=4{,}24-0{,}2=4{,}04\text{ m}$$

Usvaja se stvarni početak ojačanja na 3,9 m od oslonca.

## 4. Kontrola napona u nosaču

4.1 Kontrola napona na mestu maksimalnog momenta savijanja.

$M_{max}$ = 2781,4 kNm $\quad T_{odg}$ = 344,1 kN

$$\sigma=\frac{M_{\max}}{W}=\frac{278140}{18633{,}1}=14{,}93\ \text{kN/cm}^2<\sigma_{dop}$$

$$\tau=\frac{T\cdot S_y}{I_y\cdot t_w}=\frac{344{,}1\cdot 10437{,}5}{1444062\cdot 1}=2{,}49\ \text{kN/cm}^2<\tau_{dop}$$

Kontrola uporednog napona

$$\sigma_x=\frac{M_{\max}}{I_y}\cdot\frac{d}{2}=\frac{278140}{1444062{,}5}\cdot\frac{150}{2}=14{,}45\ \text{kN/cm}^2<\sigma_{dop}$$

$$\tau_{xz}=\frac{T\cdot S_{y,0}}{I_y\cdot t_w}=\frac{344{,}1\cdot 7625}{1444062\cdot 1}=1{,}82\ \text{kN/cm}^2<\tau_{dop}$$

Napon usled lokalnog pritiska točka dizalice

Efektivna širina na kojoj deluje lokalni pritisak to čka je jednaka: $b_{eff}=3{,}2\cdot\sqrt[3]{\frac{I_{y,f}}{t_w}}$

$I_{y,f}$ –zbir sopstvenih momenata inercije šine i gornje no žice

Šina tip 49 $\quad I_{ys}$=1819 cm$^4$

$$I_{y,f}=I_{ys}+\frac{2{,}5^3\cdot 40}{12}=1819+52{,}1=1871{,}1\ \text{cm}^4$$

$$b_{eff}=3{,}2\cdot\sqrt[3]{\frac{1871{,}1}{1}}=39{,}4\ \text{cm}$$

$$\sigma_z=\frac{\varphi\cdot P}{b_{eff}\cdot t_w}=\frac{1{,}4\cdot 280}{39{,}4\cdot 1}=9{,}95\ \text{kN/cm}^2$$

$$\tau_{zx}=0{,}2\cdot\sigma_z=0{,}2\cdot 9{,}95=1{,}99\ \text{kN/cm}^2$$

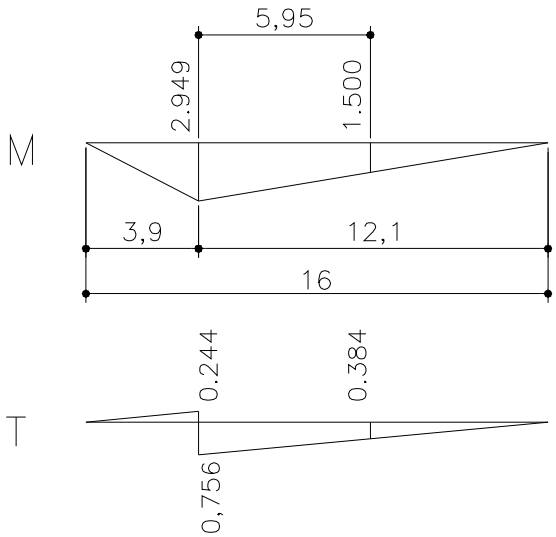
$$\sigma_u=\sqrt{\sigma_x{}^2+\sigma_z{}^2-\sigma_x\sigma_z+3\cdot\left(\tau_{zx}+\tau_{xz}\right)^2}=\sqrt{14{,}45^2+9{,}95^2-14{,}45\cdot 9{,}95+3\cdot\left(1{,}99+1{,}82\right)^2}$$

$$\sigma_u=14{,}41\ \text{kN/cm}^2<\sigma_{dop}$$

4.2 Kontrola napona na mestu maksimalne transverzalne sile

$$\tau = \frac{T_{\max} \cdot S_y}{I_y \cdot t_w} = \frac{812{,}62 \cdot 8531{,}2}{1153359 \cdot 1} = 6{,}01 \text{ kN/cm}^2 < \tau_{dop}$$

4.3 Kontrola napona na mestu ojačanja




$M_p$=280·2,949+260·1,500
$M_p$=1215,72 kNm
$T_p$=280·0,756+260·0,384
$T_p$=311,5 kN
$M_g$=2,949·(16/2)·20
$M_g$=471,84 kNm
$T_g$=20·16/2-3,9·20
$T_g$=82,0 kN

$M_{max}$ = 1,2·471,84+1,4·1215,72
$\boldsymbol{M_{max}}$ **= 2268,2 kNm**
$T_{max}$ = 1,2·82 +1,4·311,52
$\boldsymbol{T_{max}}$ **= 534,5 kN**

$$\sigma_x = \frac{M_{\max}}{W} = \frac{226820}{1153359} = 15{,}24 < 16 \text{ kN/cm}^2$$

Kontrola uporednog napona

$$\sigma_x = \frac{M_{\max}}{I_y} \cdot \frac{d}{2} = \frac{226820}{1153359} \cdot \frac{150}{2} = 14{,}75 \text{ kN/cm}^2 < \sigma_{dop}$$

$$\tau_{xz} = \frac{T_{\max} \cdot S_{y,0}}{I_y \cdot t_w} = \frac{534{,}5 \cdot 5718{,}7}{1152259 \cdot 1} = 2{,}65 \text{ kN/cm}^2 < \tau_{dop}$$

Napon usled lokalnog pritiska točka dizalice
Šina tip 49 $I_{ys}$=1819 cm$^4$

$$I_y = I_{ys} + \frac{2{,}5^3 \cdot 30}{12} = 1819 + 39{,}06 = 1858{,}1 \text{ cm}^4$$

$$b_{eff} = 3{,}2 \cdot \sqrt[3]{\frac{1858{,}1}{1}} = 39{,}3 \text{ cm}$$

$$\sigma_z = \frac{\varphi \cdot P}{b_{eff} \cdot t_w} = \frac{1{,}4 \cdot 280}{39{,}3 \cdot 1} = 9{,}97 \text{ kN/cm}^2$$

$$\tau_{zx} = 0{,}2 \cdot \sigma_z = 0{,}2 \cdot 9{,}97 = 2{,}00 \text{ kN/cm}^2$$

$$\sigma_u = \sqrt{\sigma_x^{\,2} + \sigma_z^{\,2} - \sigma_x \sigma_z + 3 \cdot (\tau_{zx} + \tau_{xz})^2} = \sqrt{14{,}75^2 + 9{,}97^2 - 14{,}75 \cdot 9{,}97 + 3 \cdot (2{,}00 + 2{,}65)^2}$$

$$\sigma_u = 15{,}32 \text{ kN/cm}^2 < \sigma_{dop}$$



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## 5. Kontrola deformacija

$$\max f \approx \frac{5{,}5 \cdot M \cdot l}{48 \cdot E \cdot I} = \frac{5{,}5 \cdot (145600 + 61950) \cdot 1600^2}{48 \cdot 21000 \cdot 1444062{,}5} = 2{,}01\,\text{cm}$$

$$\max f = 2{,}01\,\text{cm} < f_{dop} = \frac{1600}{500} = 3{,}2\,\text{cm}$$

## 6. Kontrola napona u šavovima za vezu donje nožice i rebra

Veza se ostvaruje sa dva ugaona šava $a_w$=4 mm

$$T_{max} = 812{,}62\,\text{kN}$$

$$V_{II} = \frac{812{,}62 \cdot 5718{,}7}{1153359 \cdot 2 \cdot 0{,}4} = 5{,}04\ \text{kN/cm}^2$$

$$V_{II} < \sigma_{w,dop} = 12\,\text{kN/cm}^2$$

## 7. Kontrola napona u šavovima za vezu gornje nožice i rebra

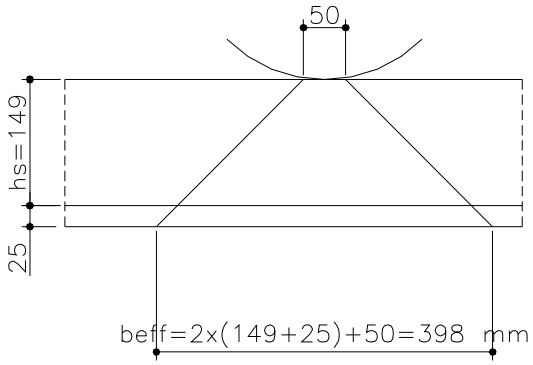
Veza se ostvaruje sa dva ugaona šava $a_w$=6 mm

$$T_{max} = 812{,}6\,\text{kN}$$

$$V_{II} = \frac{812{,}6 \cdot 5718{,}7}{1153359 \cdot 2 \cdot 0{,}6} = 3{,}36\ \text{kN/cm}^2$$

$$n = \frac{\varphi \cdot P}{b_{eff} \cdot 2 \cdot a_w} = \frac{1{,}4 \cdot 280}{39{,}8 \cdot 2 \cdot 0{,}6} = 8{,}21\ \text{kN/cm}^2$$

$$\sigma_u = \sqrt{V_{II}^{\,2} + n^2} = 8{,}87\,\text{kN/cm}^2 < \sigma_{w,dop}$$




## 8. Kontrola stabilnosti nosača na bočno-torziono izvijanje

Nosač je bočno pridržan u petinama raspona, pa je razmak tačaka bočnog pridržavanja $l_y$=1600/5=3200 cm

$i_{zf}$ - poluprečnik inercije gornje nožice

$$I_{zf} = \frac{40^3 \cdot 2{,}5}{12} = 13333{,}3\,\text{cm}$$

$$A_f = 2{,}5 \cdot 40 = 100\,\text{cm}^2$$

$$i_{zf} = \sqrt{\frac{13333{,}3}{100}} = 11{,}55\,\text{cm}$$

$$\lambda_y = \frac{l_y}{i_{yf}} = \frac{320}{11{,}55} = 27{,}7 < 40$$ **Nema opasnosti od bočno-torzionog izvijanja nosača !**



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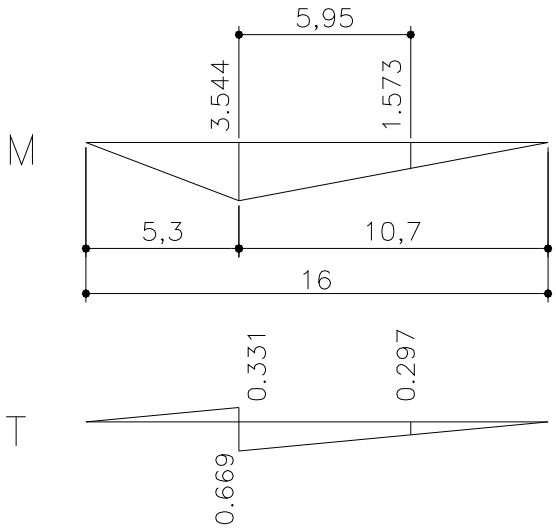
## 9. Dimenzionisanje montažnog nastavka

Montažni nastavak se predviđa na 5,3 m od levog oslonca.

### 9.1 Statički uticaji na mestu nastavka




$M_p$=280·3,544+260·1,573
$M_p$=1401,3 kNm
$T_p$=280·0,669+260·0,297
$T_p$=264,5 kN
$M_g$=3,544·(16/2)·20
$M_g$=567,0 kNm
$T_g$=20·16/2-5,3·20
$T_g$=54,0 kN

$M$ = 1,2·567,0+1,4·1401,3
***M* = 2642,3 kNm**
$T$ = 1,2·54 +1,4·264,5
***T* = 435,1 kN**

### 9.2 Raspodela presečnih sila

$$M_w = \frac{2642,2}{1444062} \cdot 281250 = 514,6\ \text{kNm} \qquad T_w = 435,1\ \text{kN}$$

$$M_f = M - M_w = 2642,2 - 514,6 = 2127,6\ \text{kN/cm}^2 \qquad T_f = 0\ \text{kN}$$

$$N_{t,f} = \frac{M_f}{h} = \frac{212760}{150 + 2,5} = 1395,2\ \text{kN}$$

### 9.3 Proračun broja zavrtnjeva na nožicama.

Usvojeni zavrtnjevi M24..10.9 sa površinom ispitnog preseka $A_s$=3,53 cm$^2$.

$$F_{s,dop} = 2 \cdot 0,5 \cdot \frac{3,53 \cdot 0,7 \cdot 90}{1,4} = 158,85\ \text{kN}$$

$$n = \frac{1395,2}{158,85} = 8,78 \qquad \textbf{Usvaja se 12 M24... 10.9}$$

### 9.4 Kontrola napona u zategnutoj nožici

$$A_{f,net} = 2,5 \cdot 40 - 4 \cdot 2,5 \cdot 2,5 = 75\ \text{cm}^2$$

$$N_{t,f,red} = 1395,2 - 4 \cdot 0,4 \cdot 158,85 = 1141,04\ \text{kN}$$

$$\sigma = \frac{1141,04}{75} = 15,21\ \text{kN/cm}^2 < \sigma_{dop} = 16\ \text{kN/cm}^2$$

### 9.5 Proračun podvezica na zategnutoj nožici

$$A_{f,p,net} > \frac{N_{t,f,net}}{\sigma_{dop}} = \frac{1141,04}{16} = 71,31\ \text{cm}^2$$

$$A_{f,p,net} = \left[(40 - 4 \cdot 2,5) + (15,5 - 2 \cdot 2,5) \cdot 2\right] \cdot t_{f,p} > 71,31\ \text{cm}^2 \qquad t_{f,p} \geq 13,98\ \text{mm}$$

**Usvajaju se podvezice = 2x155x15 i = 400x15**



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9.6 Proračun podvezica na pritisnutoj nožici

$$A_{f,p} > \frac{N_{c,f}}{\sigma_{dop}} = \frac{1395,2}{16} = 87,2\ \text{cm}^2$$

$$A_{f,p} = 4 \cdot 12 \cdot t_{f,p} > 87,2\ \text{cm}^2 \qquad t_{f,p}=18,1\ \text{mm}$$

**Usvajaju se podvezice = 4x120x20**

9.7 Proračun broja zavrtnjeva na rebru

Usvojeni zavrtnjevi M16..10.9 sa površinom ispitnog preseka $As=1,57\ \text{cm}^2$.

$$F_{s,dop} = 2 \cdot 0,5 \cdot \frac{1,57 \cdot 0,7 \cdot 90}{1,4} = 70,65\ \text{kN}$$

$$M_w' = M_w + V \cdot e = 514,6 + 435,1 \cdot 0,07 = 545,1\ \text{kNm}$$

$$n_{w,uk} = n \times m = \frac{1}{F_{s,dop}} \cdot \sqrt{V^2 + \left(\frac{6 \cdot M_w'}{h}\right)^2} = \frac{1}{70,65} \cdot \sqrt{435,1^2 + \left(\frac{6 \cdot 545,1}{1,55}\right)^2} = 30,7$$

**Usvaja se 2 x 17=34 M16 ... 10.9**

Kontrola sile u najopterećenijem zavrtnju

$$F_V = \frac{435,1}{34} = 12,8\ \text{kN}$$

$$F_M = \frac{M_w' \cdot h_{\max}}{m \cdot \sum h_i^2} = \frac{54510 \cdot 136}{2 \cdot \left[136^2 + 119^2 + 102^2 + 85^2 + 68^2 + 51^2 + 34^2 + 17^2\right]} = 62,87\ \text{kN}$$

$$F = \sqrt{62,87^2 + 12,8^2} = 64,2\ \text{kN} < F_{s,dop} = 70,65\ \text{kN}$$

9.8 Proračun podvezica na rebru

$$A_{w,p} = \frac{V}{\tau_{dop}} = \frac{435,1}{9} = 48,34\ \text{cm}^2$$

$h_p=143$ cm $\quad 2 \cdot h_p \cdot t_{w,p} = 2 \cdot 143 \cdot t_{w,p} > 48,34 \qquad t_{w,p} = 0,17$ cm

**Usvajaju se podvezice na rebru 2 =1430x6**

$$I_{w,p} = 2 \cdot 0,6 \cdot \frac{143^3}{12} = 292421\ \text{cm}^4$$

$$I_{f,p} = \left[4 \cdot b_{p,c} \cdot t_{f,p,c} + \left(b_{p1} + 2 \cdot b_{p2} - 2 \cdot n_{f1} \cdot d_{0,f}\right) \cdot t_{f,p,t}\right] \cdot \left(\frac{h - t_{f,p,t}}{2}\right)^2$$

$$I_{f,p} = \left[(4 \cdot 12) \cdot 2 + (40 + 2 \cdot 15,5 - 2 \cdot 4 \cdot 2,5) \cdot 1,5\right] \cdot \left(\frac{155 - 2,5}{2}\right)^2 = 1002925,8\ \text{cm}^4$$

$$I_p = 292421 + 1002925,8 = 1295346,5\ \text{cm}^4$$

$$W_p = \frac{1295346,5}{\frac{155}{2} + 2,0} = 16293,7\ \text{cm}^3$$

Kontrola napona u podvezicama

$$\sigma = \frac{M}{W_p} = \frac{264220}{16293,7} = 16,22\ \text{kN/cm}^2 \qquad \Delta = 1,36\% < 3\%$$



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Kontrola napona u podvezicama na rebru

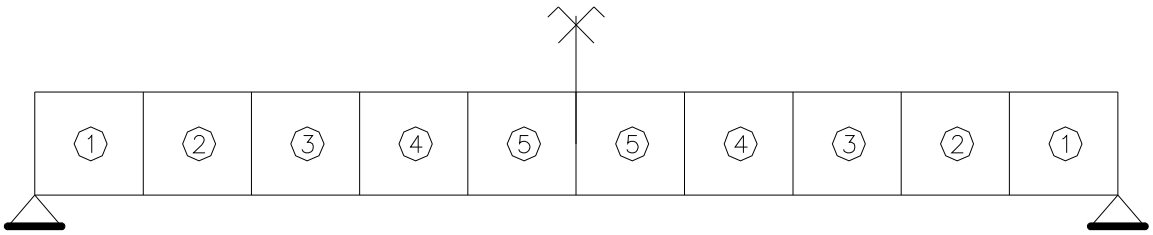
$$\sigma = \frac{M_w'}{I_{w,p}} \cdot \frac{h_p}{2} = \frac{54510}{292421} \cdot \frac{143}{2} = 13{,}33\ \text{kN/cm}^2$$

$$\tau = \frac{T}{A_{w,p}} = \frac{435{,}1}{143 \cdot 2 \cdot 0{,}6} = 2{,}54\ \text{kN/cm}^2$$

$$\sigma_u = \sqrt{\sigma^2 + 3\tau^2} = \sqrt{13{,}33^2 + 3 \cdot 2{,}54^2} = 14{,}04\ \text{kN/cm}^2$$

## 10. Kontrola stabilnosti na izbočavanje

Poprečna ukrućenja se postavljaju u desetinama raspona.




### 10.1 Kontrola stabilnosti rebra u prvom polju

$a$ = 1600 mm  $b$ = 1500 mm  $\alpha = \frac{a}{b} = \frac{1600}{1500} = 1{,}067$

$T$ = 812,6 kN  $T^*$ = 1,5·812,6 = 1218,9 kN  ( ponderisana sila )

$$k_\tau = 5{,}34 + \frac{4}{\alpha^2} = 5{,}34 + \frac{4}{1{,}07^2} = 8{,}853$$

$$\sigma_E = \frac{\pi^2 \cdot E}{12 \cdot (1 - \mu^2)} \cdot \left(\frac{t_w}{b}\right)^2 = \frac{\pi^2 \cdot 21000}{12 \cdot (1 - 0{,}3^2)} \cdot \left(\frac{1{,}0}{150}\right)^2 = 0{,}844\ \text{kN/cm}^2$$

$$\tau_{kr} = k_\tau \cdot \sigma_E = 8{,}834 \cdot 0{,}844 = 7{,}46\ \text{kN/cm}^2$$

$$\overline{\lambda}_p = \sqrt{\frac{f_y}{\tau_{kr} \cdot \sqrt{3}}} = \sqrt{\frac{24}{7{,}47 \cdot \sqrt{3}}} = 1{,}362 \quad \Rightarrow \quad \chi_p = \frac{0{,}6}{\sqrt{\overline{\lambda}_p{}^2 - 0{,}13}} = \frac{0{,}6}{\sqrt{1{,}362^2 - 0{,}13}} = 0{,}457$$

$$\tau_u = c_\tau \cdot \chi_p \cdot \frac{f_y}{\sqrt{3}} = 1{,}25 \cdot 0{,}456 \cdot \frac{24}{\sqrt{3}} = 7{,}9\ \text{kN/cm}^2$$

$$\tau^* = \frac{T^* \cdot S_y}{I_y \cdot t_w} = \frac{1218{,}9 \cdot 8531{,}2}{1153359 \cdot 1} = 9{,}02\ \text{kN/cm}^2$$

$\tau^* > \tau_u$  stabilnost nije zadovoljena, postavlja se poprečno vertikalno ukrućenje u sredini prvog polja.

$a$ = 800 mm  $b$ = 1500 mm  $\alpha = \frac{a}{b} = \frac{800}{1500} = 0{,}533$

$$k_\tau = 5{,}34 + \frac{4}{\alpha^2} = 5{,}34 + \frac{4}{0{,}533^2} = 19{,}42$$

$$\tau_{kr} = k_\tau \cdot \sigma_E = 19{,}42 \cdot 0{,}844 = 16{,}39\ \text{kN/cm}^2$$

$$\overline{\lambda}_p = \sqrt{\frac{f_y}{\tau_{kr} \cdot \sqrt{3}}} = \sqrt{\frac{24}{16{,}39 \cdot \sqrt{3}}} = 0{,}920 \quad \Rightarrow \quad \chi_p = \frac{0{,}6}{\sqrt{0{,}92^2 - 0{,}13}} = 0{,}709$$



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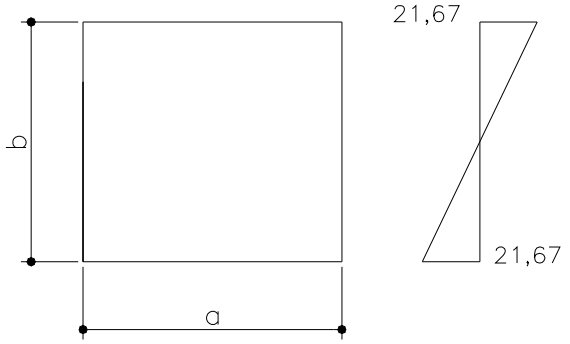
$$\tau_u = c_\tau \cdot \chi_p \cdot \frac{\sigma_v}{\sqrt{3}} = 1{,}25 \cdot 0{,}709 \cdot \frac{24}{\sqrt{3}} = 12{,}28\ \text{kN/cm}^2 < \frac{\sigma_v}{\sqrt{3}} = 13{,}86\ \text{kN/cm}^2$$

$$\tau^* = \frac{T^* \cdot S_y}{I_y \cdot t_w} = \frac{1218{,}9 \cdot 8531{,}2}{1153359 \cdot 1} = 9{,}02\ \text{kN/cm}^2 < 12{,}28\ \text{kN/cm}^2 = \tau_u$$

$\tau^* < \tau_u$ stabilnost je zadovoljena

**10.2 Kontrola stabilnosti rebra u polju do sredine raspona (peto polje)**




$a = 1600$ mm $\quad b = 1500$ mm

$$\alpha = \frac{a}{b} = \frac{1600}{1500} = 1{,}07$$

$T = 344{,}1$ kN $\quad T^* = 1{,}5 \cdot 344{,}1 = 516{,}2$ kN

$M = 2781{,}8$ kN $\quad M^* = 1{,}5 \cdot 2781{,}8 = 4172{,}1$ kN

$$\sigma = \frac{M^*}{I_y} \cdot b/2 = \frac{417210}{1444062{,}5} \cdot 75 = 21{,}67\ \text{kN/cm}^2 \qquad \psi = \frac{\sigma_1}{\sigma_2} = \frac{21{,}67}{-21{,}67} = -1$$

$k_\sigma = 23{,}9$

$$\sigma_E = \frac{\pi^2 \cdot E}{12 \cdot (1-\mu^2)} \cdot \left(\frac{t_w}{b}\right)^2 = \frac{\pi^2 \cdot 21000}{12 \cdot (1-0{,}3^2)} \cdot \left(\frac{1{,}0}{150}\right)^2 = 0{,}844\ \text{kN/cm}^2$$

$\sigma_{kr} = k_\sigma \cdot \sigma_E = 23{,}9 \cdot 0{,}844 = 20{,}17\ \text{kN/cm}^2$

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{kr}}} = \sqrt{\frac{24}{20{,}17}} = 1{,}09 \quad \Rightarrow \quad \chi_p = \frac{0{,}6}{\sqrt{\bar{\lambda}_p{}^2 - 0{,}13}} = \frac{0{,}6}{\sqrt{1{,}09^2 - 0{,}13}} = 0{,}583$$

$k_\sigma \cdot \alpha^2 = 23{,}9 \cdot 1{,}067^2 = 27{,}21 > 2$ važi kriterijum čistog izbočavanja $f = 0$

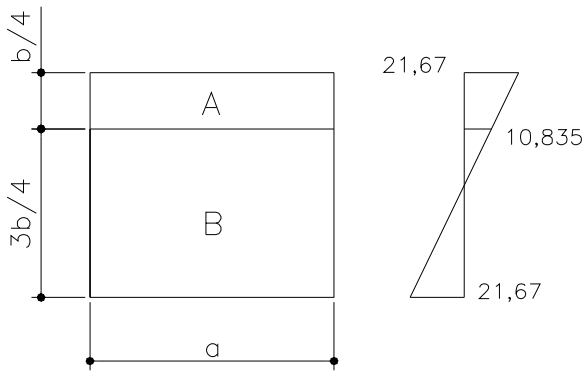
$\bar{\sigma}_u = (1 - f^2) \cdot \chi_p + f^2 \cdot \chi_c = \chi_p$

$c_\sigma = 1{,}25 - 0{,}25 \cdot \psi = 1{,}25 - 0{,}25 \cdot (-1) = 1{,}5 > 1{,}25 \quad \Rightarrow \quad c_\sigma = 1{,}25$

$\sigma_u = c_\sigma \cdot \bar{\sigma}_u \cdot f_y = 1{,}25 \cdot 0{,}583 \cdot 24 = 17{,}49\ \text{kN/cm}^2 \le \sigma_v = 24\ \text{kN/cm}^2$

$\sigma^* = 21{,}67\ \text{kN/cm}^2 > 17{,}49\ \text{kN/cm}^2 = \sigma_u$ stabilnost nije zadovoljena, postavlja se podužno ukrućenje na b/4 od gornje ivice rebra.

**Kontrola stabilnosti polja A**




$a = 1600$ mm $\quad b = 1500/4 = 375$ mm

$$\alpha = \frac{a}{b} = \frac{1600}{375} = 4{,}267$$

$$\psi = \frac{\sigma_1}{\sigma_2} = \frac{21{,}67}{10{,}835} = 0{,}5$$

$$\sigma_E = \frac{\pi^2 \cdot E}{12 \cdot (1-\mu^2)} \cdot \left(\frac{t_w}{b}\right)^2 = \frac{\pi^2 \cdot 21000}{12 \cdot (1-0{,}3^2)} \cdot \left(\frac{1{,}0}{37{,}5}\right)^2 = 13{,}5 \text{ kN/cm}^2$$

$$k_\sigma = \frac{8{,}4}{\psi + 1{,}1} = \frac{8{,}4}{0{,}5 + 1{,}1} = 5{,}25$$

$$\sigma_{kr} = k_\sigma \cdot \sigma_E = 5{,}25 \cdot 13{,}5 = 70{,}9 \text{ kN/cm}^2$$

$$\bar{\lambda}_p = \sqrt{\frac{\sigma_v}{\sigma_{kr}}} = \sqrt{\frac{24}{70{,}9}} = 0{,}582 < 0{,}7 \qquad \chi_p = 1 \quad \Rightarrow \quad \sigma_u = \sigma_v = 24 \text{ kN/cm}^2$$

$\sigma^* = 24 \text{ kN/cm}^2 < \sigma_u = 24 \text{ kN/cm}^2$ stabilnost je zadovoljena

$$k_\tau = 5{,}34 + \frac{4}{\alpha^2} = 5{,}34 + \frac{4}{4{,}27^2} = 5{,}52$$

$$\tau_{kr} = k_\tau \cdot \sigma_E = 13{,}5 \cdot 5{,}52 = 74{,}52 \text{ kN/cm}^2$$

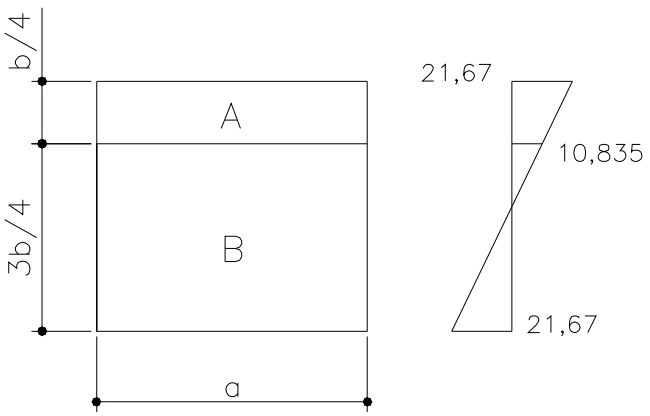
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\tau_{kr} \cdot \sqrt{3}}} = \sqrt{\frac{24}{74.52 \cdot \sqrt{3}}} = 0{,}431 \qquad \bar{\lambda}_p < 0{,}7 \;\Rightarrow\; \chi_p = 1 \;\Rightarrow\; \tau_u = \frac{f_y}{\sqrt{3}} = 13{,}86 \text{ kN/cm}^2$$

$$\tau = \frac{T^*}{h \cdot t_w} = \frac{516{,}2}{150 \cdot 1} = 3{,}44 \text{ kN/cm}^2 < \tau_u = 13{,}86 \text{ kN/cm}^2$$ stabilnost je zadovoljena

Kontrola uporednog napona

$$\left(\frac{\sigma^*}{\sigma_u}\right)^2 + \left(\frac{\tau^*}{\tau_u}\right)^2 = \left(\frac{21{,}67}{24}\right)^2 + \left(\frac{3{,}44}{13{,}86}\right)^2 = 0{,}877 < 1{,}0$$

**Kontrola stabilnosti polja B**




$a = 1600$ mm $\qquad b = 1125$ mm

$$\alpha = \frac{a}{b} = \frac{1600}{1125} = 1{,}422$$

$$\psi = \frac{\sigma_1}{\sigma_2} = \frac{21{,}67}{-10{,}835} = -2$$

$$\sigma_E = \frac{\pi^2 \cdot E}{12 \cdot (1-\mu^2)} \cdot \left(\frac{t_w}{b}\right)^2 = \frac{\pi^2 \cdot 21000}{12 \cdot (1-0{,}3^2)} \cdot \left(\frac{1{,}0}{112{,}5}\right)^2 = 1{,}50 \text{ kN/cm}^2$$

$$k_\sigma = 5{,}98 \cdot (1-\psi)^2 = 5{,}98 \cdot 3^2 = 53{,}82$$

$$\sigma_{kr} = k_\sigma \cdot \sigma_E = 53{,}82 \cdot 1{,}50 = 80{,}73 \text{ kN/cm}^2$$

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{kr}}} = \sqrt{\frac{24}{80{,}73}} = 0{,}545 \;\Rightarrow\; \chi_p = 1{,}0 \;\Rightarrow\; \sigma_u = f_y = 24{,}0 \text{ kN/cm}^2$$

$\sigma_u = c_\sigma \cdot \bar{\sigma}_u \cdot f_y = 1{,}25 \cdot 0{,}816 \cdot 24 = 24{,}49 > 24{,}0 \text{ kN/cm}^2 \Rightarrow \quad \sigma_u = \sigma_v = 24 \text{ kN/cm}^2$

$\sigma^* = 10{,}835 \text{ kN/cm}^2 < \sigma_u = 24 \text{ kN/cm}^2$ stabilnost je zadovoljena



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$$k_\tau = 5{,}34 + \frac{4}{\alpha^2} = 5{,}34 + \frac{4}{1{,}42^2} = 7{,}318$$

$$\tau_{kr} = k_\tau \cdot \sigma_E = 7{,}318 \cdot 1{,}50 = 10{,}986 \text{ kN/cm}^2$$

$$\overline{\lambda}_p = \sqrt{\frac{f_y}{\tau_{kr} \cdot \sqrt{3}}} = \sqrt{\frac{24}{10{,}986 \cdot \sqrt{3}}} = 1{,}123 \qquad \chi_p = \frac{0{,}6}{\sqrt{1{,}123^2 - 0{,}13}} = 0{,}564$$

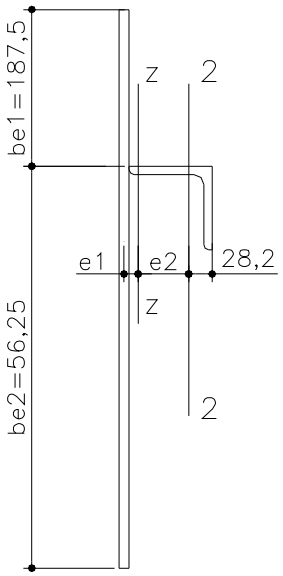
$$\tau_u = c_\tau \cdot \chi_p \cdot \frac{f_y}{\sqrt{3}} = 1{,}25 \cdot 0{,}564 \cdot \frac{24}{\sqrt{3}} = 9{,}77 \text{ kN/cm}^2 < \frac{f_y}{\sqrt{3}} = 13{,}86 \text{ kN/cm}^2$$

$$\tau^* = \frac{T^*}{h \cdot t_w} = \frac{516{,}2}{150 \cdot 1} = 3{,}44 \text{ kN/cm}^2 < \tau_u = 9{,}77 \text{ kN/cm}^2$$ stabilnost je zadovoljena

Kontrola uporednog napona

$$\left(\frac{\sigma^*}{\sigma_u}\right)^2 + \left(\frac{\tau^*}{\tau_u}\right)^2 = \left(\frac{10{,}835}{24}\right)^2 + \left(\frac{3{,}44}{9{,}77}\right)^2 = 0{,}328 < 1.0$$

**Provera ukrućenog polja**




Predpostavlja se ukrućenje L100x100x10
Geometrijske karakteristike ukrućenja:
$A$=19,2 cm$^2$ $I$=177 cm$^4$

$$e_1 + e_2 = t_w / 2 + 10{,}0 - 2{,}82 = 7{,}68 \text{ cm}$$

$$b_{e1} = \frac{1}{2} \cdot 0{,}665 \cdot \sqrt{k_{\sigma 1} \cdot \frac{E}{f_y}} = \frac{1}{2} \cdot 0{,}665 \cdot \sqrt{5{,}25 \cdot \frac{21000}{24}} = 22{,}53 \text{ cm}$$

$$b_{e1} > b_1 / 2 = \frac{37{,}5}{2} = 18{,}75$$ usvaja se $b_{e1}$=18,75 cm

$$b_{e2} = \frac{1}{2} \cdot 0{,}665 \cdot \sqrt{k_{\sigma 2} \cdot \frac{E}{f_y}} = \frac{1}{2} \cdot 0{,}665 \cdot \sqrt{53{,}82 \cdot \frac{21000}{24}} = 72{,}2 \text{ cm}$$

$$b_{e2} > b_2 / 2 = \frac{112{,}5}{2} = 56{,}25$$ usvaja se $b_{e2}$=56,25 cm

$$A_s = 19{,}2 + (56{,}25 + 18{,}75) \cdot 1 = 94{,}2 \text{ cm}^2$$

$$e_1 = \frac{19{,}2 \cdot 7{,}68}{94{,}2} = 1{,}57 \text{ cm} \qquad e_2 = 7{,}68 - 1{,}57 = 6{,}11 \text{ cm}$$

$$I_s = 177 + \frac{(56{,}25 + 18{,}75) \cdot 1^3}{12} + 19{,}2 \cdot 6{,}11^2 + (56{,}25 + 18{,}75) \cdot 1 \cdot 1{,}57^2 = 1078{,}6 \text{ cm}^4$$

$$\delta = \frac{A_s}{b \cdot t_w} = \frac{19{,}2}{150 \cdot 1} = 0{,}128$$

$$\gamma = \frac{I_s}{0{,}092 \cdot b \cdot t_w^{\,3}} = \frac{1078{,}6}{0{,}092 \cdot b \cdot t^3} = 78{,}2$$

$$\alpha = \frac{a}{b} = \frac{1600}{1500} = 1{,}067 \qquad \psi = \frac{\sigma_1}{\sigma_2} = \frac{21{,}67}{-21{,}67} = -1$$



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Za ukrućenu ploču sa nomograma se očitavaju koeficijenti: $k_\sigma = 84 \quad k_\tau = 13{,}5$

$$\sigma_E = \frac{\pi^2 \cdot E}{12 \cdot \left(1-\mu^2\right)} \cdot \left(\frac{t_w}{b}\right)^2 = \frac{\pi^2 \cdot 21000}{12 \cdot \left(1-0{,}3^2\right)} \cdot \left(\frac{1{,}0}{150}\right)^2 = 0{,}844 \text{ kN/cm}^2$$

$$\sigma_{kr} = k_\sigma \cdot \sigma_E = 84 \cdot 0{,}844 = 70{,}9 \text{ kN/cm}^2$$

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{kr}}} = \sqrt{\frac{24}{70{,}9}} = 0{,}582 < 0{,}7 \qquad \chi_p = 1$$

$$\frac{\sigma_{kr}}{\sigma_c} = k_\sigma \cdot \alpha^2 \cdot \frac{1+\sum\delta}{1+\sum\gamma} = 84 \cdot 1{,}067^2 \cdot \frac{1+0{,}128}{1+78{,}2} = 1{,}36 \qquad 1 < \frac{\sigma_{kr}}{\sigma_c} < 2{,}0$$

$$f = 2 - \frac{\sigma_{kr}}{\sigma_c} = 2 - 1{,}36 = 0{,}64$$

$$\sigma_c = \frac{1}{\alpha^2} \cdot \frac{1+\sum\gamma}{1+\sum\delta} \cdot \sigma_E = \frac{1}{1{,}067^2} \cdot \frac{1+78{,}2}{1+0{,}128} \cdot 0{,}844 = 52{,}05$$

$$\bar{\lambda}_p = \sqrt{\frac{\sigma_v}{\sigma_{kr}}} = \sqrt{\frac{24}{52{,}05}} = 0{,}679$$

Koristimo krivu izvijanja B $\alpha$=0,339

$$\beta = 1 + 0{,}339 \cdot \left(0{,}679 - 0{,}2\right) + 0{,}679^2 = 1{,}623$$

$$\chi_c = \frac{2}{\left(1{,}623 + \sqrt{1{,}623^2 - 4 \cdot 0{,}679^2}\right)} = 0{,}796$$

$$\bar{\sigma}_u = \left(1-f^2\right) \cdot \chi_p + f^2 \cdot \chi_c = (1 - 0{,}64^2) \cdot 1 + 0{,}64^2 \cdot 0{,}796 = 0{,}916$$

$$c_\sigma = 1{,}25 - 0{,}25 \cdot \psi = 1{,}25 - 0{,}25 \cdot (-1) = 1{,}5 \;\Rightarrow\; c_\sigma = 1{,}25$$

$$\sigma_u = c_\sigma \cdot \bar{\sigma}_u \cdot f_y = 1{,}25 \cdot 0{,}916 \cdot 24 = 27{,}5 > 24{,}0 \text{ kN/cm}^2 \Rightarrow \quad \sigma_u = f_y$$

$\sigma^* < \sigma_u$ stabilnost je zadovoljena

$$\tau_{kr} = k_\tau \cdot \sigma_E = 13{,}5 \cdot 0{,}844 = 11{,}4 \text{ kN/cm}^2$$

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\tau_{kr} \cdot \sqrt{3}}} = \sqrt{\frac{24}{11{,}4 \cdot \sqrt{3}}} = 1{,}102 \qquad \chi_p = \frac{0{,}6}{\sqrt{1{,}102^2 - 0{,}13}} = 0{,}576$$

$$\tau_u = c_\tau \cdot \chi_p \cdot \frac{f_y}{\sqrt{3}} = 1{,}25 \cdot 0{,}576 \cdot \frac{24}{\sqrt{3}} = 9{,}98 \text{ kN/cm}^2$$

$$\tau^* = \frac{516{,}2}{150 \cdot 1} = 3{,}44 \text{ kN/cm}^2 < \tau_u = 9{,}98 \text{ kN/cm}^2 \quad \text{stabilnost je zadovoljena}$$

Kontrola uporednog napona

$$\left(\frac{\sigma}{\sigma_u}\right)^2 + \left(\frac{\tau}{\tau_u}\right)^2 = \left(\frac{21{,}67}{24}\right)^2 + \left(\frac{3{,}44}{9{,}98}\right)^2 = 0{,}934 < 1.0$$



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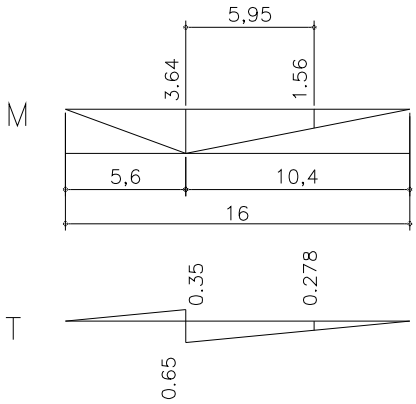
### 10.3 Kontrola stabilnosti rebra u polju četiri

Uticaji u polju četiri




$M_p$=280·3,64+260·1,56
$M_p$=1424,8 kNm
$T_p$=280·0,65+260·0,278
$T_p$=254,3 kN
$M_g$=3,64·(16/2)·20
$M_g$=582,4 kNm
$T_g$=20·16/2-5,6·20
$T_g$=48,0 kN

$M$ = 1,2·582,4+1,4·1424,8
***M* = 2693,6 kNm** $\Rightarrow$ $M^*$ = 1,5·2693,6 = 4040,4 kN
$T$ = 1,2·48 +1,4·254,28
***T* = 413,6 kN** $\Rightarrow$ $T^*$ = 1,5·413,6 = 620,4 kN

$$\sigma^* = \frac{M^*}{I_y} \cdot b/2 = \frac{404040}{1444062,5} \cdot 75 = 20,98 \text{ kN/cm}^2$$

$$\tau^* = \frac{T^*}{d \cdot t_w} = \frac{620,4}{150 \cdot 1} = 4,14 \text{ kN/cm}^2$$

$\sigma_u = c_\sigma \cdot \overline{\sigma}_u \cdot \sigma_v = 1,25 \cdot 0,583 \cdot 24 = 17,49 \text{ kN/cm}^2$ Granični napon za neukrućeno polje

$\sigma^* = 20,98 \text{ kN/cm}^2 > 17,49 \text{ kN/cm}^2$

Potrebno je podužno ukrućenje kao u polju pet

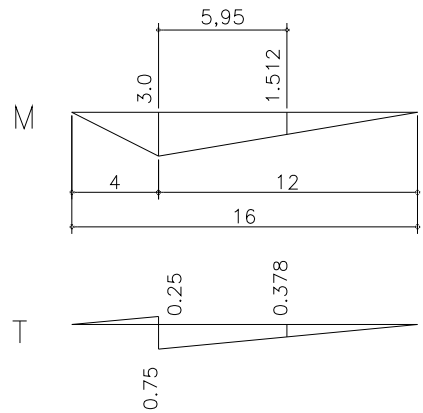
Kontrola uporednog napona za ukrućeno polje

$$\left(\frac{\sigma}{\sigma_u}\right)^2 + \left(\frac{\tau}{\tau_u}\right)^2 = \left(\frac{20,98}{24}\right)^2 + \left(\frac{4,14}{9,98}\right)^2 = 0,936 < 1,0$$

**Stabilnost je zadovoljena**

### 10.4 Kontrola stabilnosti rebra u polju tri

Uticaji u polju tri




$M_p$=280·3,0+260·1,512
$M_p$=1233,1 kNm
$T_p$=280·0,75+260·0,378
$T_p$=308,3 kN
$M_g$=3,0·(16/2)·20
$M_g$=480,0 kNm
$T_g$=20·16/2-4,0·20
$T_g$=80,0 kN

$M$ = 1,2·480,0+1,4·1233,1
***M* = 2302,4 kNm** $M^*$ = 1,5·2302,4 = 3453,6 kN
$T$ = 1,2·80 +1,4·308,3
***T* = 527,62 kN** $T^*$ = 1,5·527,62 = 791,4 kN

$$\sigma_1^* = \frac{M^*}{I_{y,1}} \cdot b/2 = \frac{345360}{1153359} \cdot 75 = 22,46 \text{ kN/cm}^2$$

$$\sigma_2^* = \frac{M^*}{I_{y,2}} \cdot b/2 = \frac{345360}{1444062,5} \cdot 75 = 17,94 \text{ kN/cm}^2$$



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$$\sigma^* = \frac{22,46 + 17,94}{2} = 20,2$$

$$\tau^* = \frac{T^*}{h \cdot t_w} = \frac{791,4}{150 \cdot 1} = 5,28\,\text{kN/cm}^2$$

$\sigma_u = c_\sigma \cdot \overline{\sigma}_u \cdot f_y = 1,25 \cdot 0,583 \cdot 24 = 17,49\,\text{kN/cm}^2$ Granični napon za neukrućeno polje

$\sigma^* = 20,2\,\text{kN/cm}^2 > 17,49\,\text{kN/cm}^2$

. Potrebno je podužno ukrućenje kao u polju pet

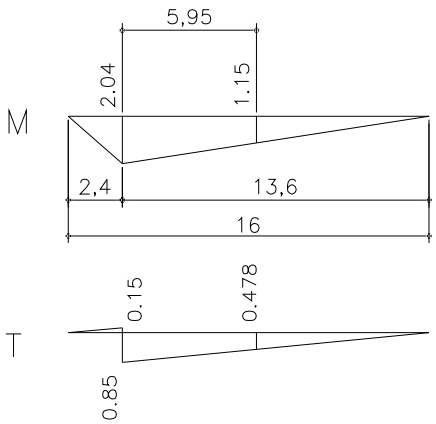
Kontrola uporednog napona za ukrućeno polje

$$\left(\frac{\sigma^*}{\sigma_u}\right)^2 + \left(\frac{\tau^*}{\tau_u}\right)^2 = \left(\frac{20,2}{24}\right)^2 + \left(\frac{5,28}{9,98}\right)^2 = 0,988 < 1.0$$

**Stabilnost je zadovoljena**

### 10.5 Kontrola stabilnosti rebra u polju dva

Uticaji u polju dva




$M_p$=280·2,04+260·1,15
$M_p$=870,2 kNm
$T_p$=280·0,85+260·0,478
$T_p$=362,3 kN
$M_g$=2,04·(16/2)·20
$M_g$=326,4 kNm
$T_g$=20·16/2-2,4·20
$T_g$=112,0 kN

$M$ = 1,2·326,4+1,4·870,2
***M* = 1609,96 kNm** $M^*$= 1,5·1609,96 = 2414,9 kN
$T$ = 1,2·112 +1,4·362,3
***T* = 641,6 kN** $T^*$= 1,5·641,6 = 962,4 kN

$$\sigma^* = \frac{M^*}{I_y} \cdot b/2 = \frac{241490}{1153359} \cdot 75 = 15,7\text{kN/cm}^2$$

$$\tau^* = \frac{T^*}{h \cdot t_w} = \frac{962,4}{150 \cdot 1} = 6,41\,\text{kN/cm}^2$$

$\sigma_u = c_\sigma \cdot \overline{\sigma}_u \cdot f_y = 1,25 \cdot 0,583 \cdot 24 = 17,49\,\text{kN/cm}^2$ Granični napon za neukrućeno polje

$\tau_{kr} = k_\tau \cdot \sigma_E = 8,834 \cdot 0,844 = 7,46\,\text{kN/cm}^2$ Granični napon za neukrućeno polje

$$\left(\frac{\sigma^*}{\sigma_u}\right)^2 + \left(\frac{\tau^*}{\tau_u}\right)^2 = \left(\frac{15,7}{17,49}\right)^2 + \left(\frac{6,41}{7,46}\right)^2 = 1,54 > 1,0$$

Stabilnost nije zadovoljena potrebno je ukru ćenje kao za polje pet.

Kontrola uporednog napona za ukrućeno polje

$$\left(\frac{\sigma^*}{\sigma_u}\right)^2 + \left(\frac{\tau^*}{\tau_u}\right)^2 = \left(\frac{15,7}{24}\right)^2 + \left(\frac{6,41}{9,98}\right)^2 = 0,804 < 1.0$$

**Stabilnost je zadovoljena**



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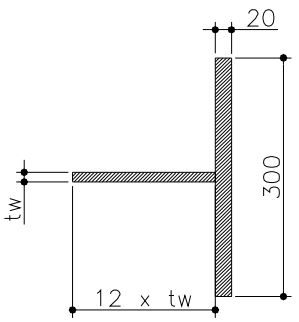
## 11. Proračun oslonačkog poprečnog ukrućenja




Geometrijske karakteristike ukrućenja sa pripadajućim delom rebra:

$$A = 30 \cdot 2{,}0 + 12 \cdot 1{,}0 \cdot 1{,}0 = 72\ \text{cm}^2$$

$$I = \frac{30^3 \cdot 2{,}0}{12} = 4500\ \text{cm}^4$$

$$l_i = 0{,}75 \cdot 150 = 112{,}5\ \text{cm}$$

$$i = \sqrt{\frac{4500}{72}} = 7{,}91\ \text{cm} \qquad \lambda = \frac{112{,}5}{7{,}91} = 14{,}22$$

$$\lambda_v = 92{,}9 \qquad \bar{\lambda} = \frac{14{,}523}{92{,}9} = 0{,}153 \quad \bar{\lambda} < 0{,}2 \ \Rightarrow \ \chi = 1$$

$$\sigma_{i,dop} = \chi \cdot \sigma_{dop} = 1 \cdot 16 = 16\ \text{kN/cm}^2$$

$$\sigma = \frac{812{,}6}{72} = 11{,}29\ \text{kN/cm}^2 < \sigma_{i,dop}$$

Kontrola napona u šavovima za prijem reakcije oslonca (šavovi za vezu oslonačkog ukrućenja i rebra nosača). Predpostavljaju se dva ugaona šava $a_w$=6mm $l_w$=100$a_w$=600 mm.

$$V_{II} = \frac{R}{2 \cdot l_w \cdot a_w} = \frac{812{,}62}{2 \cdot 60 \cdot 0{,}6} = 11{,}3\ \text{kN/cm}^2 < \sigma_{w,dop} = 12\ \text{kN/cm}^2$$



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## 12. Specifikacija materijala

| OBJEKAT: | | | | | | | | strana: | 1 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Dimenzije | | | Masa | | |
| Broj | Oznaka elementa | Materijal | Komada | Širina (mm) | Debljina (mm) | Dužina (mm) | g (kg/m) | Po komadu (kg) | Ukupno (kg) |
| 1 | POS 1 - nožica | Č0362 | 4 | 300 | 25 | 3870 | 58.88 | 227.85 | 911.39 |
| 2 | POS 2 - nožica | Č0362 | 2 | 400 | 25 | 1400 | 78.50 | 109.90 | 219.80 |
| 3 | POS 3 - nožica | Č0362 | 2 | 400 | 25 | 6800 | 78.50 | 533.80 | 1067.60 |
| 4 | POS 4 - rebro | Č0362 | 1 | 1500 | 10 | 5270 | 117.75 | 620.54 | 620.54 |
| 5 | POS 5 - rebro | Č0362 | 1 | 1500 | 10 | 10670 | 117.75 | 1256.39 | 1256.39 |
| 6 | POS 6 - podužno ukrućenje | Č0362 | 7 | L100/100 | 10 | 1590 | 15.10 | 24.01 | 168.06 |
| 7 | POS 7 - podužno ukrućenje | Č0362 | 1 | L100/100 | 10 | 345 | 15.10 | 5.21 | 5.21 |
| 8 | POS 8 - podužno ukrućenje | Č0362 | 1 | L100/100 | 10 | 945 | 15.10 | 14.27 | 14.27 |
| 9 | POS 9 - podvezica ukrućenja | Č0362 | 16 | L100/100 | 10 | 800 | 15.10 | 12.08 | 193.28 |
| 10 | POS 10 - podvezica ukrućenja | Č0362 | 2 | L80/80 | 10 | 280 | 11.90 | 3.33 | 6.66 |
| 11 | POS 11 - čeone ploče | Č0362 | 2 | 300 | 20 | 1600 | 47.10 | 75.36 | 150.72 |
| 12 | POS 12 - poprečno ukrućenje | Č0362 | 12 | 125 | 10 | 1470 | 9.81 | 14.42 | 173.09 |
| 13 | POS 13 - poprečno ukrućenje | Č0362 | 10 | 175 | 10 | 1470 | 13.74 | 20.19 | 201.94 |
| 14 | POS 14 - podvezice | Č0362 | 4 | 120 | 20 | 950 | 18.84 | 17.90 | 71.59 |
| 15 | POS 15 - podvezice | Č0362 | 2 | 155 | 15 | 500 | 18.25 | 9.13 | 18.25 |
| 16 | POS 16 - podvezice | Č0362 | 1 | 400 | 15 | 500 | 47.10 | 23.55 | 23.55 |
| 17 | POS 17 - podvezice | Č0362 | 2 | 280 | 6 | 1430 | 13.19 | 18.86 | 37.72 |
| 18 | POS 18 - pas pločice | Č0362 | 12 | 50 | 30 | 95 | 11.78 | 1.12 | 13.42 |
| 19 | POS 19 - pas pločice | Č0362 | 10 | 50 | 30 | 145 | 11.78 | 1.71 | 17.07 |
| | | | | | | | | Σ = | 5170.57 |
| | | | | | | | | | |
| | | | | | | | Ukupno +3%: | | **5325.68** |



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