

7. VAJA: TORZIJA

7.1. Zasnova: (šice - priložen list)

$$i = 42$$

$$l_k = 100 - i \text{ [cm]} = 100 - 42 = 58 \text{ cm}$$

$$L = 4,0 \text{ m}; \quad l_1 = 2,5 \text{ m}; \quad l_2 = 1,5 \text{ m}$$

$$F_g = 2,4 \text{ kN}$$

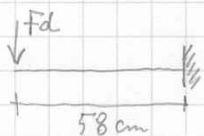
$$F_q = 0,5 + \frac{i}{20} = 0,5 + \frac{42}{20} = 2,6 \text{ kN}$$

les C30 M

nijaki S235

7.2. Dimensioniranje konzole

$$F_d = 1,35 \cdot F_g + 1,5 \cdot F_q = 1,35 \cdot 2,4 \text{ kN} + 1,5 \cdot 2,6 \text{ kN} = 6,6 \text{ kN}$$



$$V_d = F_d = 6,6 \text{ kN}$$

$$M_d = F_d \cdot l_k = 6,6 \cdot 58 = 382,8 \text{ kNcm}$$



• kontrole upogibnih napetosti:

$$\sigma_{mol} = \frac{M_d}{\frac{b l^2}{6}} \leq f_{mol} = 1,846 \text{ kN/cm}^2 \rightarrow \text{IZBRSEM } b = 12 \text{ cm}$$

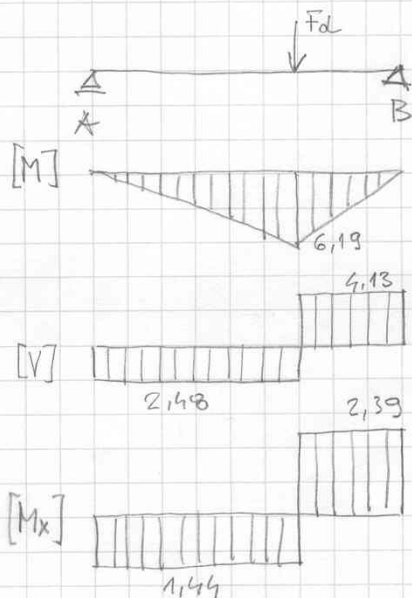
$$l = \sqrt{\frac{M_d \cdot 6}{b \cdot f_{mol}}} = \sqrt{\frac{382,8 \cdot 6 \text{ kNcm cm}^2}{12 \text{ cm} \cdot 1,846 \text{ kN}}} = 10,18 \rightarrow \text{IZBRSEM } b/h = 12/12 \text{ cm}$$

• kontrole strižnih napetosti:

$$\tau_{ol} = \frac{V_d}{\frac{2}{3} b h} \leq f_{vol} = 0,185 \text{ kN/cm}^2$$

$$\tau_{ol} = \frac{6,6}{\frac{2}{3} \cdot 12 \text{ cm} \cdot 12 \text{ cm}} = 0,069 \frac{\text{kN}}{\text{cm}^2} < f_{vol} \checkmark \text{ PRERAZ USTREJA}$$

7.3 Dimenzioniranje vzdolžnega nosilca



$$M_{d,max} = F_d \cdot \frac{l_1 \cdot l_2}{L} = 6.6 \cdot \frac{2.5 \cdot 1.5}{4} = 6.19 \text{ kNm}$$

$$V_d^A = F_d \cdot \frac{l_2}{L} = 6.6 \cdot \frac{1.5}{4} = 2.48 \text{ kN}$$

$$V_d^B = F_d \cdot \frac{l_1}{L} = 6.6 \cdot \frac{2.5}{4} = 4.13 \text{ kN}$$

$$M_{xd} = F_d \cdot l_k = 6.6 \cdot 0.58 = 3.83 \text{ kNm}$$

$$M_{xd}^A = M_{xd} \cdot \frac{l_2}{L} = 3.83 \cdot \frac{1.5}{4} = 1.44 \text{ kNm}$$

$$M_{xd}^B = M_{xd} \cdot \frac{l_1}{L} = 3.83 \cdot \frac{2.5}{4} = 2.39 \text{ kNm}$$

- Kontrola upogibnih napetosti:

$$\sigma_{md} = \frac{M_{d,max}}{\frac{b \cdot h^3}{6}} \leq f_{md} = 1.846 \text{ kN/cm}^2 \quad b = h$$

$$h = \sqrt[3]{\frac{M_{d,max} \cdot 6}{f_{md}}} = \sqrt[3]{\frac{6.19 \text{ kNm} \cdot 6 \text{ cm}^2}{1.846 \text{ kN}}} = 12.62 \text{ cm}$$

$$\text{IZBRSEM } b/h = 14/14 \text{ cm}$$

- Kontrola strižnih napetosti:

$$\tau_{dl} = \tau_{dl}(V_d^B) + \tau_{dl}(M_{xd}^B)$$

$$\left. \begin{aligned} \tau_{dl}(V_d) &= \frac{V_d}{\frac{2}{3} b h} \\ \tau_{dl}(M_{xd}) &= \frac{M_{xd}}{W_p} \end{aligned} \right\} < f_{vd} = 0.185 \text{ kN/cm}^2$$

$$W_p^a = \frac{\pi b^2 h}{16} \quad ; \quad W_p^b = \frac{\pi \cdot b \cdot h^2}{16} \quad \left\{ \begin{array}{l} \text{za kvadratni presek} \\ \text{sta enake} \end{array} \right.$$

$$W_p = \frac{\pi \cdot 14^3 \text{ cm}^3}{16} = 538.78 \text{ cm}^3$$

$$\tau_{dl}(V_d) = \frac{4.13 \text{ kN}}{\frac{2}{3} \cdot 14^2 \text{ cm}^2} = 0.032 \text{ kN/cm}^2$$

$$\tau_{dl}(M_{xd}) = \frac{2.39 \text{ kNm}}{538.78} = 0.444 \text{ kN/cm}^2$$

$$\tau_{dl}(V_d) + \tau_{dl}(M_{xd}) > f_{vd}$$

$\Rightarrow$ PRERISAN
OSTROGA

Izbrani nivo dimenzij: ($\tau_d(V_d)$ zamenjamo):

$$W_p = \frac{M_{xd}}{f_{vd}} = \frac{239 \text{ kNm} \cdot \text{cm}^2}{0,185 \text{ kN}} = 1291,89 \text{ cm}^2$$

$$b = \sqrt[3]{\frac{16 W_p}{\pi}} = \sqrt[3]{\frac{16 \cdot 1291,89}{\pi}} = 18,74 \text{ cm} \rightarrow \text{Izberem } b/h = 20/20 \text{ cm}$$

Pomožno kontrole napetosti:

$$\tau_d = \frac{4,13 \text{ kN}}{\frac{2}{3} 20^2 \text{ cm}^2} + \frac{239}{\frac{\pi \cdot 20^3}{16}} = 0,168 < 0,185 \text{ kN/cm}^2 \checkmark$$

$$\frac{\tau_d}{f_{vd}} = \frac{0,168}{0,185} = 0,908 \rightarrow 90,8\%$$

$$\frac{\sigma_{md}}{f_{md}} = \frac{\frac{M_d \cdot 6}{b \cdot h^2}}{f_{md}} = \frac{\frac{619,6}{20^3}}{1,846} = 0,251 \rightarrow 25,1\%$$

7.4. Izračun povosa po silo F (glej priložene liste)

$\rightarrow$ mejno stanje uporabnosti $\rightarrow \mu_g = \mu_q = 1,0$

$$l_1 = 2,5 \text{ m}; l_2 = 1,5 \text{ m}; L = 4,0 \text{ m}; l_k = 0,58 \text{ m}$$

$$F_{dg} = 2,0 \text{ kN}$$

$$F_{dq} = 2,6 \text{ kN}$$

$$M_{xdg} = F_{dg} \cdot l_k = 2,0 \cdot 0,58 = 1,16 \text{ kNm}$$

$$M_{xdq} = F_{dq} \cdot l_k = 2,6 \cdot 0,58 = 1,51 \text{ kNm}$$

$$E_{0,mean} = 1200 \text{ kN/cm}^2$$

$$G = 75 \text{ kN/cm}^2$$

$$J_{nos} = \frac{20 \cdot 20^3}{12} = 13333,3 \text{ cm}^4$$

① Pomik nosilca

$$\mu_g: \mu_{1,inst}^{(nosil.)} = \frac{F_{dg} \cdot l_1^2 \cdot l_2^2}{3 E J \cdot L} = \frac{2,0 \text{ kN} \cdot 250^2 \text{ cm}^2 \cdot 150^2 \text{ cm}^2 \cdot \text{cm}^2}{3 \cdot 1200 \text{ kN} \cdot 13333,3 \text{ cm}^4 \cdot 400 \text{ cm}} = 0,146 \text{ cm}$$

$$\mu_{1,fin}^{(nosil.)} = \mu_{1,inst}^{(nosil.)} \left(1 + k_{def}^P\right) = 0,146 (1 + 0,8) = 0,263 \text{ cm}$$

$$\mu_q: \mu_{2,inst}^{(nosil.)} = \frac{F_{dq} \cdot l_1^2 \cdot l_2^2}{3 E J \cdot L} = \frac{2,6 \cdot 250^2 \cdot 150^2}{3 \cdot 1200 \cdot 13333,3 \cdot 400} = 0,19 \text{ cm}$$

$$\mu_{2,fin}^{(nosil.)} = \mu_{2,inst}^{(nosil.)} \left(1 + k_{def}^M\right) = 0,19 (1 + 0,25) = 0,238 \text{ cm}$$

2) ZASUK NOSILCA

$$M_{xdg1} = M_{xdg} \cdot \frac{l_2}{L} = 1,16 \cdot 100 \cdot \frac{1,5}{4,0} = 43,5 \text{ kNm}$$

$$M_{xdg2} = M_{xdg} \cdot \frac{l_2}{L} = 1,51 \cdot 100 \cdot \frac{1,5}{4,0} = 56,6 \text{ kNm}$$

$$\tan \theta_g = \frac{M_{xdg1} \cdot l_1}{G \cdot J_P} = \frac{43,5 \cdot 250 \text{ kNm} \cdot \text{cm} \cdot \text{cm}^2}{75 \cdot 15708 \text{ kN} \cdot \text{cm}^4} = 0,009$$

$$\tan \theta_z = \frac{M_{xdg2} \cdot l_1}{G \cdot J_P} = \frac{56,6 \cdot 250}{75 \cdot 15708} = 0,012$$

$$J_P = \frac{\pi b^3 h^3}{16(l^2 + h^2)} = \frac{\pi \cdot 20^3 \cdot 20^3}{16(20^2 + 20^2)} = 15708 \text{ cm}^4$$

$$g: u_{1,g, \text{inst}}(\text{zasuk}) = l_k \cdot \tan \theta_g = 58 \text{ cm} \cdot 0,009 = 0,52 \text{ cm}$$

$$z: u_{2,z, \text{inst}}(\text{zasuk}) = l_k \cdot \tan \theta_z = 58 \text{ cm} \cdot 0,012 = 0,70 \text{ cm}$$

3) POMIK KONZOLE

$$J_{\text{konz}} = \frac{12 \cdot 12^3}{12} = 1728 \text{ cm}^4$$

$$u_{2,g, \text{fin}}(\text{zasuk}) = 0,52(1+0,8) = 0,936 \text{ cm}$$

$$u_{2,z, \text{fin}}(\text{zasuk}) = 0,70(1+0,25) = 0,875 \text{ cm}$$

$$g: u_{1, \text{inst}}(\text{konz}) = \frac{F_{dg} \cdot l_k^3}{3E J_{\text{konz}}} = \frac{2,0 \cdot 58^3 \text{ cm}^3 \text{ cm}^2 \text{ kN}}{3 \cdot 1200 \text{ kN} \cdot 1728 \text{ cm}^4} = 0,063 \text{ cm}$$

$$u_{1, \text{fin}}(\text{konz}) = u_{1, \text{inst}}(\text{konz}) (1 + \epsilon_{\text{def}}) = 0,063 (1 + 0,8) = 0,113 \text{ cm}$$

$$z: u_{2, \text{inst}}(\text{konz}) = \frac{F_{dz} \cdot l_k^3}{3E J_{\text{konz}}} = \frac{2,6 \cdot 58^3}{3 \cdot 1200 \cdot 1728} = 0,082 \text{ cm}$$

$$u_{2, \text{fin}}(\text{konz}) = u_{2, \text{inst}}(\text{konz}) (1 + \epsilon_{\text{def}}) = 0,082 (1 + 0,25) = 0,103 \text{ cm}$$

KONTROLE POVRŠOV:

MEJNE VREDNOSTI POMIKOV:

	TRENUTNI POM.	KONČNI POM.
NOSILEC	$l/300$	$l/200$
KONZOLA	$l/150$	$l/100$

$$u_{2, \text{inst}}(\text{NOSIL}) = 0,19 \text{ cm} < l/300 = 400/300 = 1,33 \text{ cm} \checkmark$$

$$u_{2, \text{inst}}(\text{KONZOLE}) = u_{2, \text{inst}}(\text{KONZ}) + u_{2,z}(\text{ZASUK}) = 0,082 + 0,70 = 0,782 \text{ cm}$$

$$u_{2, \text{inst}}(\text{KONTROLE}) = 0,782 \text{ cm} < l_k/150 = \frac{58}{150} = 0,387 \text{ cm} //$$

→ povečam prečnik
(NAJBOLJE PREČEZ NOSILCA)

$$M_0 = 0 \rightarrow M_{net} = M_1 + M_2$$

$$M_{net, fin} (NOSILEC) = \overset{M_{1, net, fin}}{0,263} + \overset{M_{2, net, fin}}{0,238} = 0,501 \text{ cm} < \frac{L}{200} = \frac{400}{200} = 2 \text{ cm}$$

$$M_{net, fin} (KONTOLA) = \overset{(M_{1, fin} (KONTOLA) + M_{1, fin} (NOSILEC))}{(0,936 + 0,113)} + \overset{(M_{2, fin} (KONTOLA) + M_{2, fin} (NOSILEC))}{(0,875 + 0,103)} =$$

$$= 2,03 \text{ cm} < \frac{L_k}{100} = \frac{58}{100} = 0,58 \text{ cm} //$$

→ prečisti prerez
(NAJBOLJE PREZ NOSILCA)

• OPOMBA:

- V SPLOŠNEM JE POTREBNO KONTROLIRATI TUDI KONČNI SKUPNI POMIK - KONSTRUKCIJSKO ZAHTEVANA OMEJITEV POMIKA

$$M_{net, fin} (KONTOLA - SKUPNI) = M_{net, fin} (NOSILEC) + M_{net, fin} (KONTOLA) = 2,53 \text{ cm}$$

7.5. DIMENZIONIRANJE PRIKLJUČKOV (kontrola na vzdolžni²)
(NI OBVEZNO)

$$N_{td} = \frac{M_d}{a} - Q_d$$

$$N_{cd} = \frac{M_d}{a} + Q_d$$