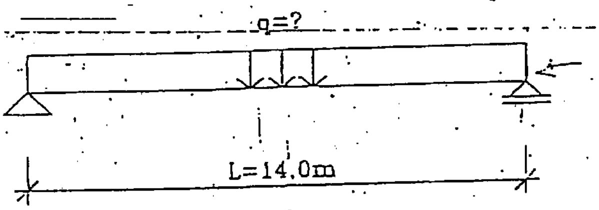
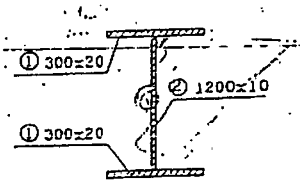
OSNOVE METALNIH KONSTRUKCIJA

1. ZADATAK

Odrediti maksimalnu vrednost opterećenja q (kN/m) koje može da prenese pun limeni nosač I-preseka formiran zavarivanjem. Nožice nosača su 300x20, rebro 1200x10, a podužni ugaoni šavovi za vezu rebra sa nožicama su a=3mm. Rebro nosača ukrućeno je poprečnim ukrućenjima u desetinama raspona. Nosač je kontinualno bočno pridržan u nivou pritisnute nožice. Raspon nosača je L=14,0m. Osnovni materijal je Č0361 - I slučaj opterećenja, a dopušteni ugib L/500.



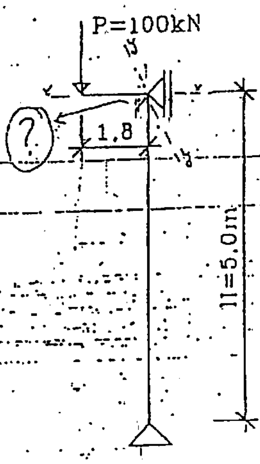


2. ZADATAK

a) Dimenzionisati stub prikazan na skici, kao valjani I profil. Pri proračunu smatrati da je stub bočno pridržan na mestima oslonaca.

b) Dimenzionisati konzolu i njenu vezu sa stubom u zavarenoj izradi (direktnim zavarivanjem, bez čeone ploče).

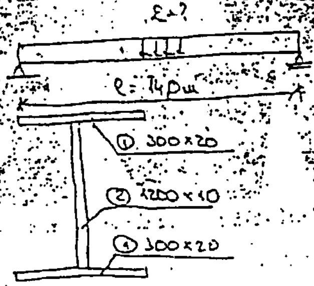
Opterećenje i geometrija nosača prikazani su na skici. Osnovni materijal je Č0361 - II slučaj opterećenja.



3. ZADATAK

Sračunati i konstruisati u razmeri 1:10 montažni nastavak štapa izrađenog od valjanog profila IPE400 prema površini poprečnog preseka. Predvideti obostrane podvezice na nožicama. Nastavak izvesti pomoću visokovrednih zavrtnjeva klase čvrstoće 10.9 sa punom silom pritezanja ($v_1 = 0,8$; $\mu = 0,4$; $v_2 = 1,40$). Osnovni materijal je Č0562 - I slučaj opterećenja.

(14. VII 1997 / 1)

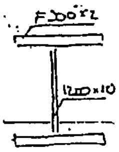


- $a = 3$ mm
- подужна усрушка на $l' = 1,4$ m
- континуално бочно придржан у нивоу прит. појаса

Č0361 — I сл. оптер. → $\sigma_{dop} = 16,0$ kN/cm², $\tau_{dop} = 9,0$ kN/cm², $\sigma_{B,dop} = 12,0$ kN/cm²

$f_{dop} = \frac{L}{500}$

$M = \frac{ql^2}{8} = 2450 \cdot q$



$I = 590520,0$ cm⁴ $\quad I_{noj} = 446520$ cm⁴

$A = 240$ cm² $\quad I_{reb} = 144000$ cm⁴

$W = 9524,52$ cm³

$S_x = 5460$

- средина распона

$M = \frac{ql^2}{8} = 2450,0 \cdot q$ cm²

$\sigma = \frac{M}{W} = \frac{2450,0\, q}{9524,52} \leq 16,0 \Rightarrow q_1 = 0,622$ kN/cm $= 62,2$ kN/m ✓

$f = \frac{5}{384}\frac{ql^4}{EI} = \frac{5}{384}\frac{q \cdot 1400^4}{2,1 \cdot 10^4 \cdot 590520} = 4,0336\, q$

$4,0336\, q \leq \frac{l}{500} \Rightarrow q_2 = 0,6942$ kN/cm $= 69,42$ kN/m ✓

- шав

$V_{II} = \frac{Q \cdot S_x}{I \cdot 2 \cdot a_s}$; $Q_{max} = R = \frac{1400 \cdot q}{2}$

$V_{II} = \frac{\frac{1400 \cdot q}{2} \cdot 5460}{590520,0 \cdot 2 \cdot 0,3} = 10,7871\, q$ cm

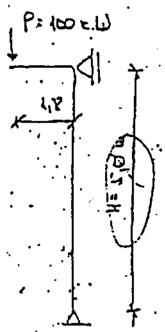
$\sigma_u = \sqrt{V_{II}^2} = 10,7871\, q \leq 12$ kN/cm²

$q_3 \leq 1,112$ kN/cm $= 111,2$ kN/m ✓

$q = \min\{q_1, q_2, q_3\} = \min\{62,2;\ 69,42;\ 111,2\} = 62,2$ kN/m

$q = 62,2$ kN/m

$\tau = \frac{ql/2 \cdot S}{I \cdot t_{reb}} \leq \tau_{dop}$ ✓



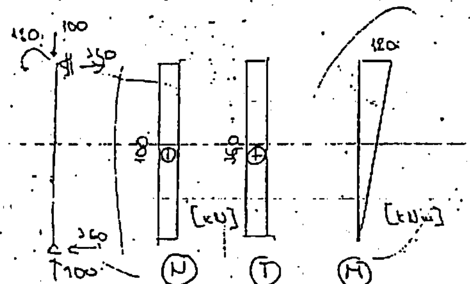
а) димен. ваљани I; добро фиксиран на местима ослонаца

б) конзола директно заварена

Č0361, II случ. оптер.

$\sigma_{dop} = 18\ kN/cm^2$　　$\sigma_v = 240\ MPa$

τ_{dop} =

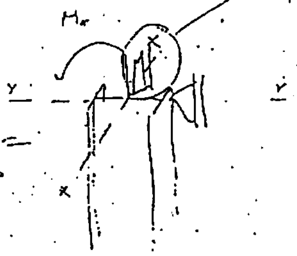
а) 

— димензионисање се врши за пресек на врху стуба

(?)

$M = P \cdot a = 100\ kN \cdot 1,2\ m = 120\ kNm$

$R = \frac{M}{h} = \frac{120}{5} = 360\ kN$



$W = \frac{M}{\sigma_{dop}} =$

p. 218 з.2　а.1) избор попречног пресека

— претпоставимо I400

$A = 118\ cm^2$; $W_x = 1460\ cm^3$; $i_x = 15,7$; $I_x = 29210\ cm^4$; $I_D = 80\ cm^4$

$S_x = 857\ cm^3$　$W_y = 149\ cm^3$　$i_y = 3,13$; $I_y = 1160\ cm^4$

$max|\sigma| = \sigma_{Mx} + \sigma_N = \frac{120 \cdot 10^2}{1460} + \frac{100}{118} = 13,18\ kN/cm^2 < \sigma_{dop} = 18,0\ kN/cm^2$

$k_{\lambda x(y)} \sigma_N + k_{mx}\theta \cdot \sigma_{Mx} < \sigma_{dop}$

$\sigma_N = \frac{N}{A} =$　　$\sigma_{Mx} = \frac{M_x}{W_x}$

— виткости у равни управној на x-x осу

$l_x = l_y = 500\ cm$

$\lambda_x = \frac{l_{ix}}{i_x} = \frac{500}{15,7} = 31,85$

$\bar{\lambda}_x = \frac{\lambda_x}{\lambda_v} = \frac{31,85}{92,9} = 0,34$

— крива извијања „А" (за x-x), $\alpha = 0,206$

- витост у (y-y)

$\lambda_y = \frac{500}{3,13} = 159,74$

$\bar{\lambda}_y = \frac{159,74}{92,9} = 1,72$

- крива извијања „B" (y-y), $\alpha = 0,339$

-

$k_{nx(y)} = 1 + \frac{\alpha(\bar{\lambda}_{x(y)} - 0,2)}{1 - \bar{\lambda}^2_{x(y)} \cdot \bar{\sigma}}$; $\bar{\sigma} = \gamma \frac{\sigma_N}{\sigma_v} = 1,33 \cdot \frac{0,847}{24} = 0,047$

$k_{nx} = 1 + \frac{0,206(0,34 - 0,2)}{1 - 0,34^2 \cdot 0,047} = 1,029$

$k_{ny} = 1,6$

} $\Rightarrow k_n = k_{ny} = 1,6$

$k_{mx} = \frac{\beta_x}{1 - \bar{\lambda}_x^2 \cdot \bar{\sigma}} \overset{стр}{=} \frac{0,66}{1 - 0,34^2 \cdot 0,047} = 0,6636$

$\Theta = \frac{\sigma_v}{\sigma_d} \geq 1,0$

- JUS U.E7.101, табела 4, стр. 676 (нови!)

$\sigma_d = \alpha_p \cdot \sigma_v \cdot \chi_M \leq \sigma_v$

$\alpha_p = \frac{W_{x\,pl}}{W_x} = \frac{2 S_x}{W_x} = \frac{2 \cdot 857,0}{1460} = 1,174$

χ_M) $\bar{\lambda}_D = \sqrt{\alpha_p \frac{\sigma_v}{\sigma_{cr,d}}}$

$\sigma_{cr,d} = \phi \cdot \sqrt{\sigma_{vd}^2 + \sigma_{wd}^2}$

$\phi = \frac{\sqrt{k + \rho^2} \pm \rho}{\sqrt{k + \rho^2}}$

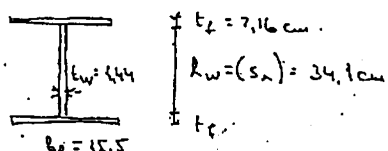
- табела 2, стр. 678а, $\Rightarrow \rho = 0 \Rightarrow \phi = 1$

$\rightarrow \sigma_{vd} = \eta_t \frac{\pi}{l_t \cdot W_x} \sqrt{G \cdot E \cdot J_d \cdot I_y} = \eta_t \frac{0,41 \cdot 10^5}{l_t \cdot W_x} \sqrt{J_d \cdot J_y}$

(?) $l_t = 500$ cm ; стр. 678,а $\Rightarrow \eta_t = 1,77$

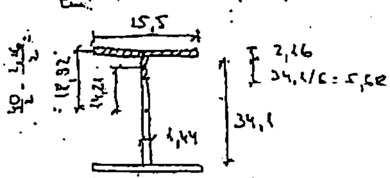
$J_d = \frac{1}{3}(2 \cdot b_f \cdot t_f^3 + h_w \cdot t_w^3) =$

(?) стр. 733 $\neq 170,0$ $= \frac{1}{3}(2 \cdot 15,5 \cdot 2,16^3 + 34,1 \cdot 1,44^3) = 138,08$ cm⁴



$\sigma_{vd} = 1,77 \cdot \frac{0,41 \cdot 10^5}{500 \cdot 1460} \sqrt{138,08 \cdot 1160} = 39,73 \frac{kN}{cm^2}$ ($\sigma_{vd} = 44,15$, за $I_d = 170$)

$\rightarrow \sigma_{wd} = \frac{\pi^2 \cdot E}{\lambda^2_{ky}} = \frac{2,07 \cdot 10^5}{\lambda^2_{ky}}$



$\rightarrow \lambda_{ky} = \frac{l_y}{i_{ky}\sqrt{\eta_y}}$; $\eta_y \overset{678а,\ табл.2}{=} 1,77$

$l_y = 500$ (доњи притиснут на местима ослонаца)

14.07.1997

IPE 400

VV 10.9 → σ_{a2}

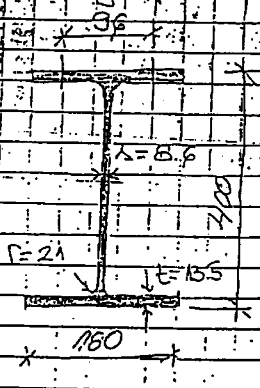
$\mu = 0.8$

$\nu = 0.4$

$\gamma_2 = 1.40$

0.0562

I случај оптерећења: $\sigma_{dop} = 24 \frac{kN}{cm^2}$ $\sigma_{a2} = 90 \frac{kN}{cm^2}$



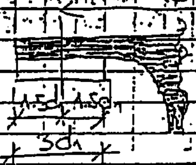
$A = 84.5\ cm^2$

подвезице на ножици:

- могућа ширина унутрашње подвезице

$2b_{podv} \le b - s - 2r = 18 - 0.86 - 2 \cdot 2.1 = 12.94\ cm$

$b_{1,podv} \le 6.47\ cm$



$96 - s - 2r = 3d_1$

$d_1 = \frac{96 - 0.86 - 2 \cdot 2.1}{3}$

$d_1 = 1.51$??

$d_1 \le \frac{b_{podv}}{3}$

$d_1 \le \frac{6.4}{3}$

$d_1 \le 2.13\ cm$

усвојено: VV M20xl 10.9

$A^{neto}_{podv, nož} \ge A^{neto}_{nož}$

$[(b_{podv} - 2d_1) + 2 \cdot (b_{1,podv} - d_1)] \cdot t^{nož}_{podv} \ge (b - 2d_1) \cdot t$

$t^{nož}_{podv} \ge \frac{(b - 2d_1) \cdot t}{[(b_{podv} - 2d_1) + 2 \cdot (b_{1,podv} - d_1)]} = \frac{(18 - 2 \cdot 2.1) \cdot 1.35}{[(18 - 2 \cdot 2.1) + 2 \cdot (6.4 - 2.1)]} = 0.83\ cm$

$t^{nož}_{podv} = 10\ mm$

усвојене подвезице на ножици: ⌿180x10 + 2⌿64x10

Број вијака на појасници:

$F_p = \nu_1 \, \sigma_{0,2} \cdot A_s$

$F_{rs} = \mu \cdot \frac{F_p}{\nu_2} = \mu \cdot \frac{\nu_1 \sigma_{0,2} A_s}{\nu_2} = 0.4 \cdot \frac{0.8 \cdot 90 \cdot 2.45}{1.40} = 50.40 \text{ kN}$

$n_{пој} = \frac{A^{нето}_{пој} \cdot \sigma_{доп}}{F^{пој}_{min}} = \frac{20.1 \cdot 24}{50.4} = 9.57$ ком

F_{rs} – за IV усвојено 10 M20×l 10.9

$A_{пој} = b \cdot t = 18 \cdot 1.35 = 24.3 \text{ cm}^2$

$A^{нето}_{пој} = A_{пој} - 2d_1 = 24.3 - 2 \cdot 2.1 = 20.1 \text{ cm}^2$

$(\min d_1 = \sqrt{5 t_{s,min}} - 0.2 = \sqrt{5 \cdot 1.0} - 0.2 = 2.036 \text{ cm})$

подвезица на ребру

$\max d_1 = \sqrt{5 t_{s,min}} - 0.2 = \sqrt{5 \cdot 0.8} - 0.2 = 1.8 \text{ cm}$

усвојени су бб вијци M16×l 10.9

$h_{под} \leq h - 2c = 33.1 \text{ cm}$ усв. $h_{под} = 30 \text{ cm}$

$2 \cdot (h_{под} - 4d_1) \cdot t^{реб}_{под} \geq A^{нето}_{реб}$

$t^{реб}_{под} \geq \frac{A - 2A_{пој} - 4d_1 \cdot s}{2 \cdot (h_{под} - 4d_1)}$

$t^{реб}_{под} \geq \frac{84.5 - 2 \cdot 24.3 - 4 \cdot 1.7 \cdot 0.86}{2 \cdot (30 - 4 \cdot 1.7)} = 0.65 \text{ cm}$

$t_{под} = 8 \text{ cm}$

усвојене подвезице на ребру 2 × 300 × 0.8

потребан број вијака на ребру

$n_{реб} = \frac{A^{нето}_{реб} \cdot \sigma_{доп}}{F^{реб}_{min}}$ $A^{нето}_{реб} = A - 2A_{пој} - 4d_1 = 29.1 \text{ cm}^2$

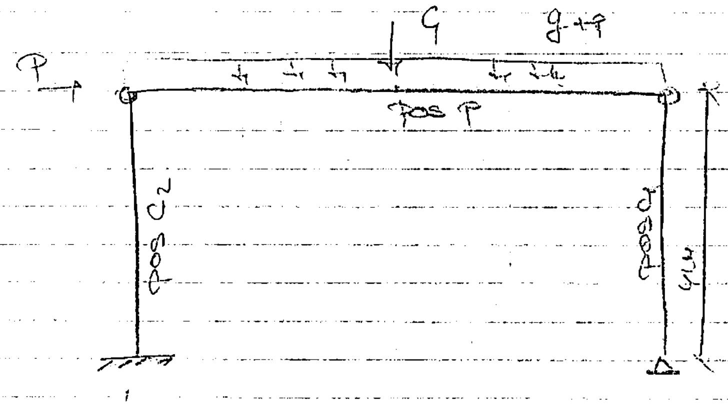
$F_{rs} = \mu \cdot \frac{\nu_1 \sigma_{0,2} A_s}{\nu_2} = 0.4 \cdot \frac{0.8 \cdot 90 \cdot 1.57}{1.40} = 32.3 \text{ kN}$

$A_s (M16) = 1.57 \text{ cm}^2$ $n_{реб} = \frac{29.1 \cdot 24}{32.3} = 21.6$

8

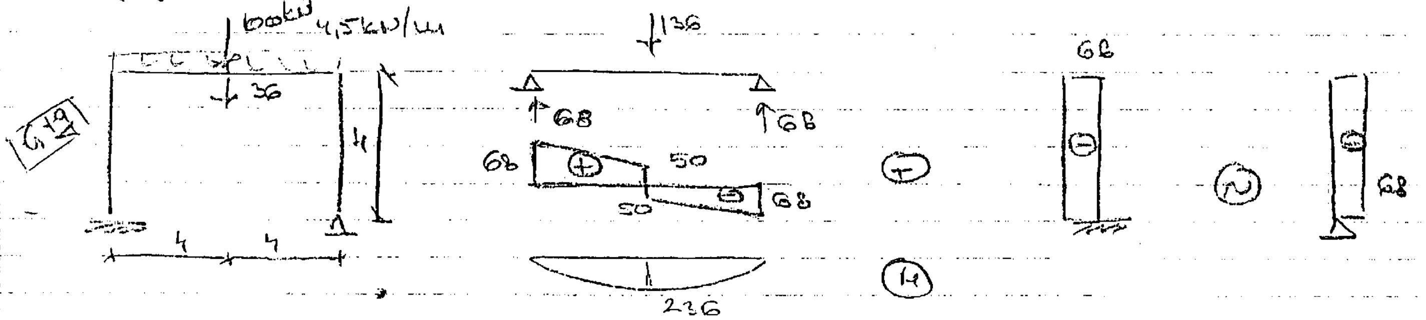
10.10.2009

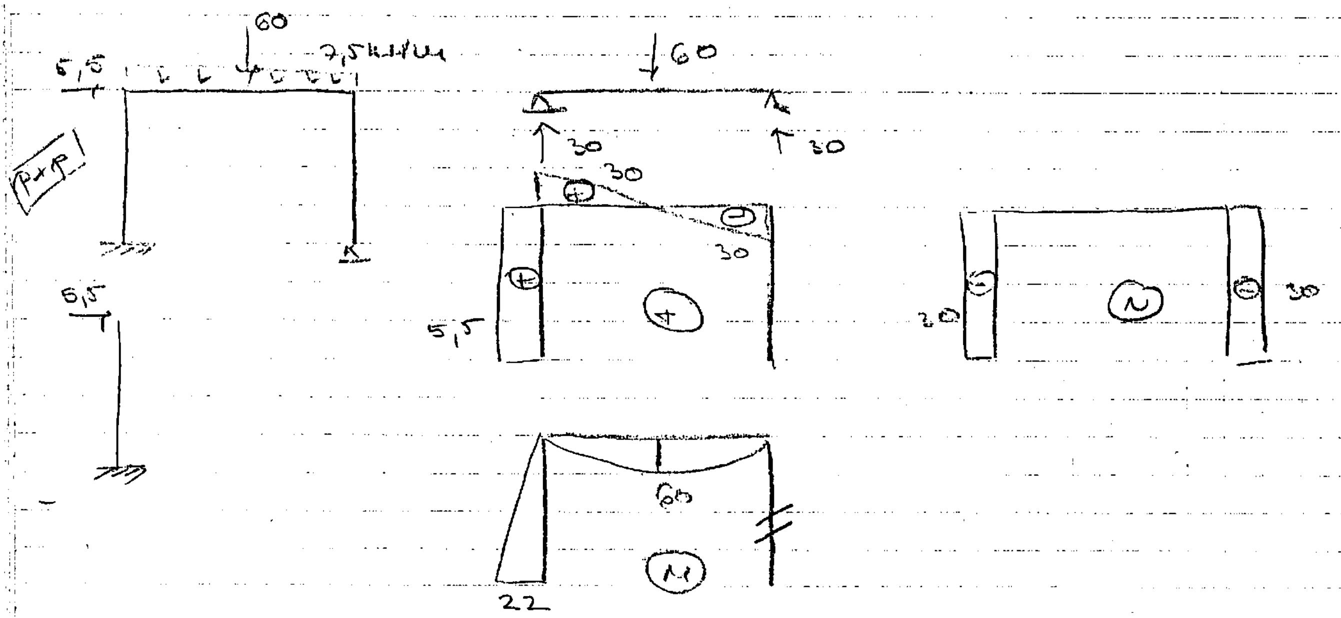
20.09.2006.



a) dimenzionisanje pos P prema JUS-u, koja je naknadno bočno pridržan; $f_{dop} = 2,7$ cm

- dijagrami presečnih sila





pos P

$f_{dop} = 2,7$ cm

$$W_{pot} = \frac{M_{max}}{\sigma_{dop}} = \frac{(236+60)\cdot 100}{16} = 1850\ cm^3$$

- usvaja se HEA 450

h = 440	A = 178	I_z = 9470	S_y = 1610
b = 300	I_y = 63720	W_z = 631	
t_w = 11,5	W_y = 2900	i_z = 7,29	
t_f = 21	i_y = 18,9		

$f_{max,1} = \frac{5}{384} \cdot \frac{\left(\frac{4,5 \cdot 2,7}{100}\right) \frac{kN}{cm} \cdot (800\ cm)^4}{21000 \cdot 63720} = 0,48\ cm$

$f_{max,2} = \frac{F \cdot l^3}{48EI} = \frac{100 \cdot 800^3}{48 \cdot 21000 \cdot 63720} = 0,8$

$f_{max} = 1,28\ cm$

* KONTROLA NAPONA

$\sigma_{max} = \frac{M_{max}}{W_y} = \frac{29600}{2900} = 10,21\ kN/cm^2 \leq 16\ kN/cm^2$

$\tau_{max} = \frac{T_{max} S_y}{I_y \cdot t_w} = \frac{(30+68) \cdot 1910}{63720 \cdot 11,5} = 2,153\ kN/cm^2 \leq 9\ kN/cm^2$

* KONTROLA UPOREDNOG NAPONA na mestu max momenta savijanja
Tada je transverzalna sila 0 u tom poprečnom preseku

$\sigma_1 = \frac{M_{max}}{I_y} \cdot \frac{h - 2t_f}{2} = \frac{29600}{63720} \cdot \frac{44 - 2 \cdot 2,1}{2} = 9,24$

$S_{y,0} = b \cdot t_f \cdot \frac{h - t_f}{2} = 1319,85$

$\tau_1 = \frac{T_{odg} \cdot S_{y0}}{t_w \cdot I_y} = \frac{50 \cdot 1319,85}{1,15 \cdot 63720} = 0,9\ kN/cm^2$

$\sigma_U = \sqrt{\sigma_1^2 + 3\tau^2} = \sqrt{9,24^2 + 3 \cdot 0,9^2} = 9,37 < 16\ kN/cm^2$

b) KONTROLA NOSIVOSTI NA SAVIJANJE I SMICANJE PREMA EC3

$M_{Ed} = 1,35 \cdot 236 + 1,5 \cdot 60 = 408,6\ kNcm$

$V_{Ed} = 1,35 \cdot 68 + 1,5 \cdot 30 = 136,8\ kN$

$S235 \Rightarrow \varepsilon = 1$ KLASIFIKACIJA POP. PRESEKA

- noseća: $\frac{(b - t_w - 2r)}{2 \cdot t_f} =$
- rebro: $\frac{(h - 2 \cdot t_f - 2r)}{t_f} =$

$\frac{W_{pot,1}}{f_{max}} = \frac{32,15 \cdot 23,5}{1} = 755,52$

$\frac{800}{52,5} = 0,54 < 1$

Површина смицања

$A_v = A - 2 \cdot b \cdot t_f + (t_w + 2r) t_f = 178 - 2 \cdot 30 \cdot 2,1 + (1,15 + 5,4) \cdot 2,1 = 65,75$

$V_{pl,Rd} = \dfrac{A_v \cdot (f_y / \sqrt{3})}{\gamma_{M0}} = \dfrac{65,755 \cdot 23,5}{\sqrt{3}} = 892,146$

$V_{Ed} / V_{pl,Rd} = \dfrac{136,8}{892,146} = 0,151 < 1$

$V_{Ed} < 0,5\, V_{pl,Rd}$ ✓ – не морамо узети редукцију носивости на моменту савијања

в) Стуб пос C_1, бочно придржан на крајевима, централно притиснут (2. веза)

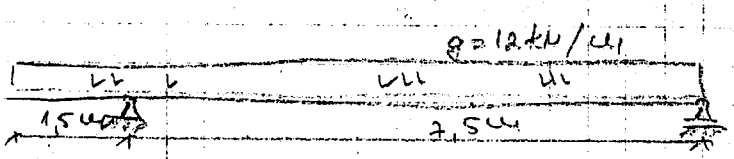
г) Стуб пос C_2, бочно придржан на крајевима, ексцентрично притиснут (6. веза)

} бочно торзионо извијање?

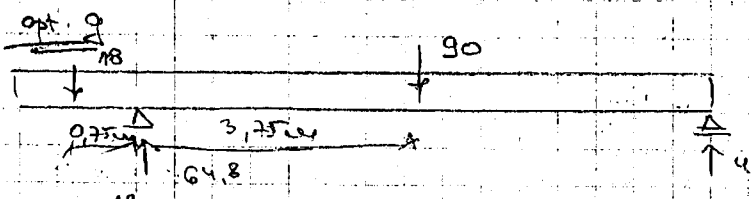
18.8 Jung

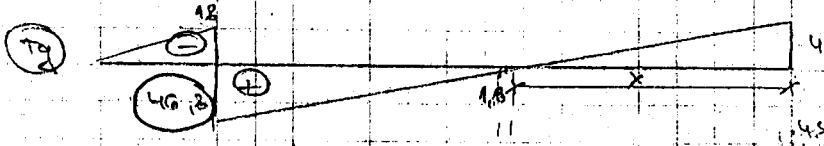
① $g = 12\ kN/m$
$p = 15\ kN/m$

$q = 15\ kN/m$



a)



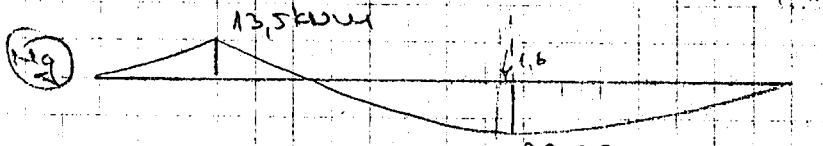


$43,2 : x = 46,8 : (7,5 - x)$

$46,8\,x = 7,5 \cdot 43,2 - 43,2\,x$

$x = 3,6\ m$

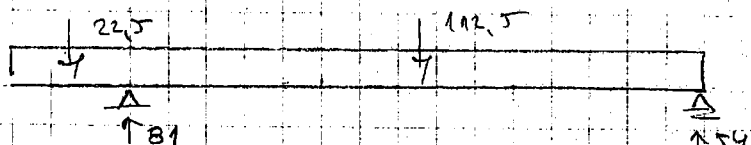
$43,2 : 3,6 = p : 0,15$

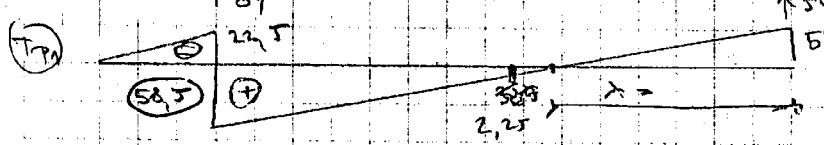


$3,6 \cdot 43,2 - 12 \cdot 3,6 \cdot \frac{3,6}{2} = 77,76$

$x^* = 3,75 \Rightarrow M_g^* = 43,2 \cdot 3,75 - 12 \frac{3,75^2}{2} = 77,62\ kNm$

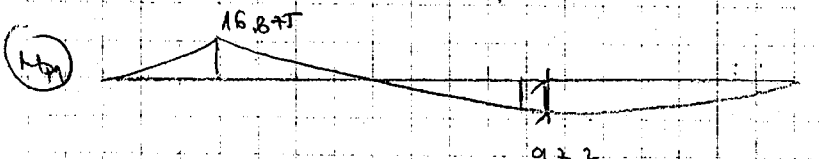
opt p1





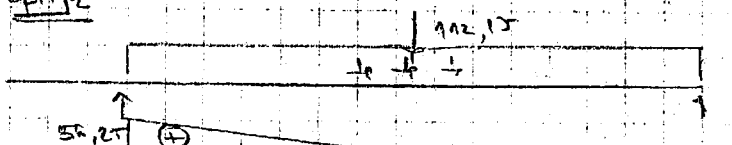
$58,5\,x = 7,5 \cdot 54 - 54\,x$

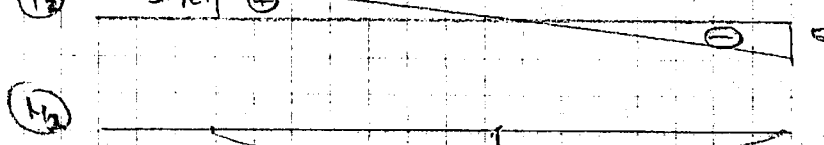
$x = 3,6$

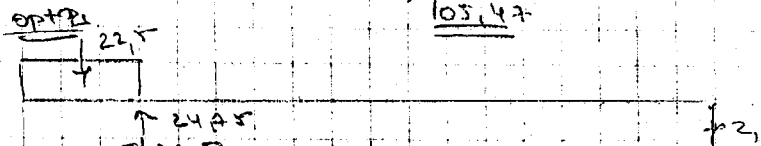


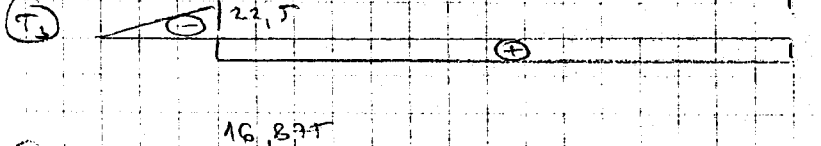
opt p2

105









a) IUS Dimenzionisanje

- kontinualno zeno propisan

I PE
S 235
Ksl. opt

$\sigma d = 16 kN/cm^2$
$\tau d = 9 kN/cm^2$

$f_{dop}^{KP} = 1 cm$
$f_{dop} = 2,5 cm$

$W_{pot} = \frac{M_{max}}{\sigma_{dop}}$ $M_{max} = 77,62 + 105,47 = \underline{183,095 kNm}$ u sredini raspona

$W_{pot} = \frac{183,095 \cdot 100}{16} = \underline{1144,34 cm^3}$

usvajamo IPE 500

$h = 500 mm$
$b_f = 200 mm$
$t_w = 10,2 mm$
$t_f = 16 mm$
$r = 21 mm$

$A = 116 cm^2$
$I_y = 48200 cm^4$
$W_y = 1930 cm^3$
$i_y = 20,4 cm$

$I_z = 2140 cm^4$
$W_z = 214 cm^3$
$i_z = 4,31 cm$

$S_y = 1100$

kontrola napona

$\sigma_{max} = \frac{M_{max}}{W_y} = \frac{183,095 \cdot 100}{1930} = 9,49 kN/cm^2 < \sigma d$ ✓

$\tau_{max} = \frac{T_{max} \cdot S_y}{t_w \cdot I_y} = \frac{(58,5 + 46,8) \cdot 1100}{1,02 \cdot 48200} = 2,35 kN/cm^2 < \tau d$ ✓

kontrola uporednog napona (na mjestu maksimalnog momenta savijanja)

$\sigma_u = \sqrt{\sigma_1^2 + 3\tau_1^2}$

$\sigma_1 = \frac{M_{max}}{I_y} \cdot \frac{h - 2 \cdot t_f}{2} = \frac{183,095 \cdot 100}{48200} \cdot \frac{(50 - 2 \cdot 1,6)}{2} = \underline{8,88 kN/cm^2} < \sigma_{dop}$ ✓

$\tau_1 = \frac{T_{odg} \cdot S_{y,0}}{t_w \cdot I_y} = \frac{[T_{max} - 3,75 \cdot (g + p)] \cdot S_{y,0}}{t_w \cdot I_y}$

$S_{y,0} = b_f \cdot t_f \cdot \frac{h - t_f}{2} = 20 \cdot 1,6 \cdot \frac{50 - 1,6}{2} = 774,4 cm^3$

$\tau_1 = \frac{(58,5 + 46,8 - 3,75 \cdot 27) \cdot 774,4}{1,02 \cdot 48200} = \underline{0,064 kN/cm^2} < \tau_{dop}$ ✓

$\sigma_u = \sqrt{8,88^2 + 3 \cdot 0,064^2} = 8,89 kN/cm^2 < \sigma_{dop} = 16 kN/cm^2$ ✓

b) KONTROLA GRANIČNIH STANJA NOSIVOSTI PREMA EC3

- uticaj na kraju vrh momenta

$M_{ed} = 1,35 \cdot 77,62 + 1,5 \cdot 105,47 = 262,992 kNm$

$V_{ed} = 1,35 \cdot 1,8 + 1,5 \cdot 2,25 = 5,805 kN$

- uticaj nad osloncem

$U_{ed} = 1,35 \cdot 46,8 + 1,5 \cdot 58,5 = 150,93$

* KLASIFIKACIJA POPREČNOG PRESEKA

Odabran materijal S235 $\Rightarrow \varepsilon = 1$

- nožica: $\frac{(b_f - t_w - 2r)/2}{t_f} = \frac{(20 - 1,02 - 2 \cdot 2,1)/2}{1,8} = 4,62$

- rebro: $\frac{(h - 2t_f - 2r)}{t_f} = \frac{(50 - 2 \cdot 1,8 - 2 \cdot 2,1)}{1,6} = 26,625$

* NOSIVOST POPREČNOG PRESEKA NA DEJSTVO SMIČUĆIH SILA

- Površina smicanja

$A_v = A - 2b \cdot t_f + (t_w + 2r) t_f = 118 - 2 \cdot 20 \cdot 1,8 + (1,02 + 2 \cdot 2,1) \cdot 1,6 = 62,64$

$V_{pl,Rd} = \frac{A_v \cdot (f_y / \sqrt{3})}{\gamma_{M0}} = \frac{62,64 \cdot (23,5)}{1 \cdot \sqrt{3}} = 849,88 kN$

* OSLONAČKI PRITISAK

$V_{Ed} / V_{pl,Rd} = 150,93 / 849,88 = 0,177 < 1$

* INTERAKCIJA SAVIJANJA I SMICANJA [P7-35]

$V_{ed} = 5,805 kN < 0,5 \cdot V_{pl,Rd} = 0,5 \cdot 849,88$ N

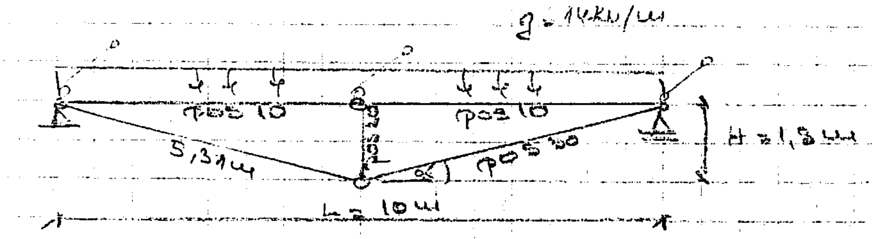
ako smičuća sila ne prelazi 50% na uticaju vrši redukciju nosivosti na momente savijanja

→ KONTROLA UGIBA, KONTROLA GRANIČNIH STANJA UPOTREBLJIVOSTI

$f_{max}^{polje} = \frac{5}{384} \frac{(g+q) \cdot l^4}{I_y \cdot E} = \frac{5}{384} \cdot \frac{(0,154+0,2) \cdot 950^4}{48200 \cdot 21000} = 1,10 cm < 2,5 cm$

$f_{max}^{prepust} = \frac{(g+q) \cdot 150}{24EI} (3 \cdot 150^3 - 750^3 + 4 \cdot 150^2 \cdot 750) = -0,57 cm < 1 cm$

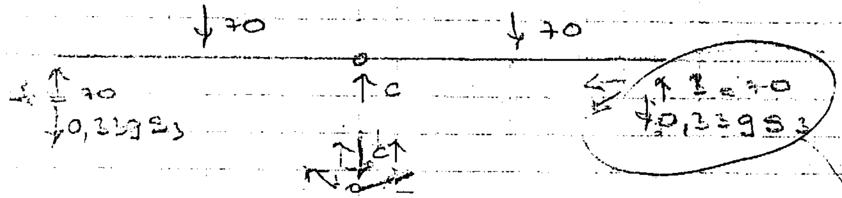
(2)



$\alpha = 19,799$

$\sin\alpha = 0,339$

a) HEA, S355, I st., JUS



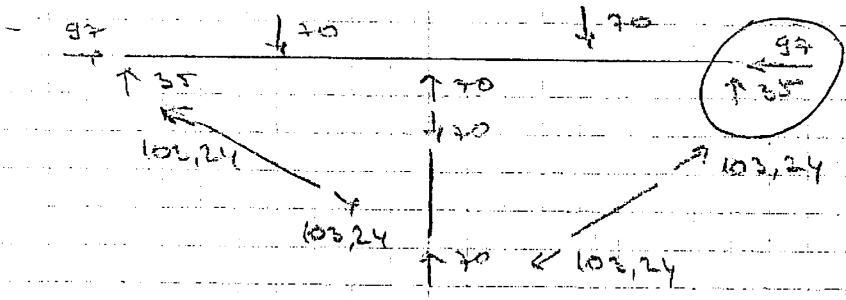
$M_C = 0: \; 70 \cdot 2,5 - B \cdot 5 + 0,339 S_3 \cdot 5 = -175 + 0,339 \cdot 5 \cdot S_3 = 0 \Rightarrow S_3 = \frac{175}{5 \cdot 0,339}$

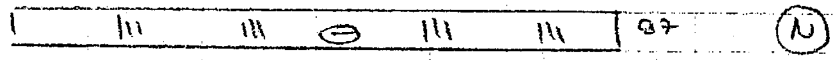
$C = 2 \cdot 0,339 S_3 \Rightarrow A + B = 140$

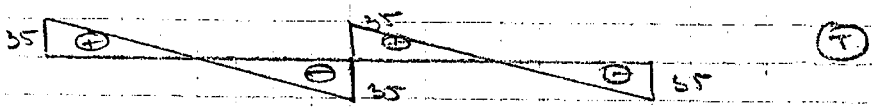
$A = B = 70$

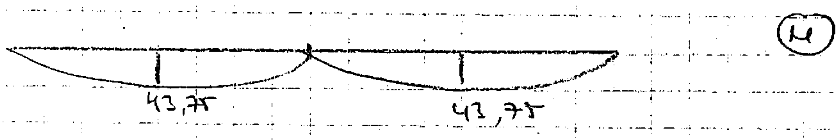
$S_3 = 103,24$

$C = 70$









Pos 10

S355 I: $\sigma_d = 24 \, kN/cm^2$, $\tau_d = 14 \, kN/cm^2$

$W_{pot} = \frac{M_{max}}{\sigma_d} = \frac{43,75 \cdot 100}{24} = 182,29 \, cm^3$

$A_{pot} = \frac{N_c}{\sigma_d} = \frac{97}{24} = 4,04 \, cm^2$

* usvojeno HEA 200

$h = 190\ mm$ $\quad A = 53,8\ cm^2$
$b_f = 200\ mm$ $\quad I_y = 3690\ cm^4$ $\quad I_z = 1340\ cm^4$ $\quad S_y = 215\ cm^3$
$s = t_w = 6,5\ mm$ $\quad W_y = 389\ cm^3$ $\quad W_z = 134\ cm^3$ $\quad W_{y,pl} = 430\ cm^3$
$t_f = 10\ mm$ $\quad i_y = 8,28\ cm$ $\quad i_z = 4,92\ cm$
$r = 18\ mm$

$$\sigma_{max} = \frac{N}{A} + \frac{M_{max}}{W_y} = \frac{92}{53,8} + \frac{4375 \cdot 100}{389} \cdot 13,05 < 24$$

$$\tau_{max} = \frac{T_{max} \cdot S_y}{t_w \cdot I_y} = \frac{33 \cdot 215}{0,65 \cdot 3690} = 3,14 \leq 14$$

$$f_{max} = \frac{5}{384} \frac{q l^4}{E I_y} = \frac{5}{384} \frac{0,14 \cdot 500^4}{21000 \cdot 3690} = \underline{1,47\ cm}$$ (gledano polovinu)

* KONTROLA EKSCENTRIČNO OPTEREĆENOG ELEMENTA

$$\boxed{k_n \cdot \sigma_n + \theta_{ky} \cdot \sigma_{My} = \sigma_{dop}}$$

$$\sigma_N = \frac{N}{A} = \frac{92}{53,8} = 1,8$$

$$\sigma_{My} = \frac{M_y}{W_y} = \frac{4375 \cdot 100}{389} = 11,25$$

$$\bar{\sigma}_N = \frac{\sigma_N}{\sigma_{N,dop}} = \frac{1,8}{24} = 0,075$$

outkost ($l_{iy} = l_{iz}$ jer zarotirano pol. nosača, u općem slučaju $l_{iy} = 1 \cdot l$, a l_{iz} gledamo u zavisnosti kako je ploča opterećena + elaborat)

~ u ravni: $\lambda_y = \frac{l_{iy}}{i_y} = \frac{500}{8,28} = 60,38$

~ izvan: $\lambda_z = \frac{l_{iz}}{i_z} = \frac{500}{4,92} = 101,63$

$$\bar{\lambda}_y = \frac{\lambda_y}{\lambda_1} = \frac{60,38}{76,4} = 0,79 \qquad \bar{\lambda}_z = \frac{\lambda_z}{\lambda_1} = 1,33$$

$\lambda_1 = 76,4$ (S355)
$\lambda_1 = 86,81$ (S275)
$\lambda_1 = 92,9$ (S235)

- koeficijent imperfekcije $\boxed{\alpha_y = 0,206}$ (a) $\qquad \boxed{\alpha_z = 0,339}$ (b)

$$\beta_y = 1 + \alpha_y (\bar{\lambda}_y - 0,2) + \bar{\lambda}_y^2 = 1 + 0,206(0,79 - 0,2) + 0,79^2 = 1,746$$

$$\beta_z = 1 + \alpha_z (\bar{\lambda}_z - 0,2) + \bar{\lambda}_z^2 = 1 + 0,339(1,33 - 0,2) + 1,33^2 = 3,152$$

$$\chi_y = \frac{2}{\beta_y + \sqrt{\beta_y^2 - 4 \bar{\lambda}_y^2}} = \frac{2}{1,746 + \sqrt{1,746^2 - 4 \cdot 0,79^2}} = 0,804$$

$$\chi_z = \frac{2}{\beta_z + \sqrt{\beta_z^2 - 4 \bar{\lambda}_z^2}} = \frac{2}{3,152 + \sqrt{3,152^2 - 4 \cdot 1,33^2}} = 0,413$$

$k_{ny} = 1 + \frac{\alpha_y(\bar{\lambda}_y - 0,2)}{1 - \bar{\lambda}_y^2 \cdot \sigma_N} = 1 + \frac{0,200(0,79 - 0,2)}{1 - 0,79^2 \cdot 0,075} = 1,127 < \frac{1}{\varkappa_y} = 1,244$

$k_{nz} = 1 + \frac{\alpha_z(\bar{\lambda}_z - 0,2)}{1 - \bar{\lambda}_z^2 \cdot \sigma_N} = 1 + \frac{0,339(1,33 - 0,2)}{1 - 1,33^2 \cdot 0,075} = 1,442 < \frac{1}{\varkappa_z} = 2,421$

$k_n = \max\{k_{ny}, k_{nz}\} = \underline{1,442}$ $\quad 1 \le k_n \le \frac{1}{\varkappa}$

$k_{my} = \frac{\beta_y}{1 - \bar{\lambda}_y^2 \sigma_N} = \frac{1}{1 - 0,79^2 \cdot 0,075} = 1,049 \ge 1 \Rightarrow k_{my} = 1,049$

ZWICHRZENIE STATECZNOŚCI NOŚNOŚCI NA ZGINANIE ... [illegible]

$\lambda_z = \frac{l_z}{b_f/\sqrt{12}} = \frac{500}{\frac{20}{\sqrt{12}}} = 86,60 \ge 40\sqrt{\frac{23,5}{f_d}} \Rightarrow$ ... kontrola na Z.7.1$_2$

pr. ...

678. strona

- rozstaw ... $l_z = 500\,cm = l_t$ (ELABORAT)

- ... [illegible]

$A_f = b_f \cdot t_f = 20 \cdot 1 = 20\,cm^2$

$A_w = A - 2 \cdot A_f = 53,8 - 2 \cdot 20 = 13,8\,cm^2$

$i_{kt} = \frac{b_f}{\sqrt{12}} \cdot \sqrt{\frac{A_f}{A_f + \frac{A_w}{6}}} = \frac{20}{\sqrt{12}} \cdot \sqrt{\frac{20}{20 + \frac{13,8}{6}}} = \underline{5,47\,cm}$

- ... krytyczne naprężenia ... $= ?$ D

$\sigma_{DV} = \eta_t \cdot \frac{0,41 \cdot 10^5}{l_t \cdot W_y} \sqrt{I_z \cdot I_t} = 1,12 \cdot \frac{0,41 \cdot 10^5}{500 \cdot 389} \cdot \sqrt{1340 \cdot 21,1} = \underline{39,7\,kN/cm^2}$

- krytyczne naprężenia dopełniające

$\lambda_{kz} = \frac{l_z}{\sqrt{\eta_z} \cdot i_{kt}} = \frac{500}{\sqrt{1,12} \cdot 5,47} = 86,37$

$\sigma_{Dw} = \pi^2 \cdot \frac{E}{\lambda_{kt}^2} = \frac{2,07 \cdot 10^5}{86,37^2} = \underline{27,75\,kN/cm^2}$

- krytyczne naprężenia giętno-skrętnego ...

$k = 1 + 0,156\left(\frac{l_z}{h}\right)^2 \cdot \frac{I_t}{I_z} = 1 + 0,156\left(\frac{500}{19}\right)^2 \cdot \frac{21,1}{1340} = 2,70$

$\phi = \frac{\sqrt{k + \rho^2} - \rho}{\sqrt{k + \rho^2}} = \frac{\sqrt{2,70 + 0,46^2} - 0,46}{\sqrt{2,70 + 0,46^2}} = 0,73$

$\sigma_{cr} = \phi\sqrt{\sigma_{DV}^2 + \sigma_{Dw}^2} = 0,73 \cdot \sqrt{39,7^2 + 27,75^2} = 35,36$

$\alpha_p = \frac{2 \cdot S_y}{W_y} = 1,105$

- relatywna bezwymiarowa smukłość $\bar{\lambda}_L = \sqrt{\frac{\alpha_p \cdot f_d}{\sigma_{cr}}} = \sqrt{\frac{1,05 \cdot 35,5}{35,36}} = 1,053$

- bezwymiarowy współ. giętno-skrętnego ... $n = 2$ za walcowane profile

$\varphi_L = \left(\frac{1}{1 + \bar{\lambda}_L^{2 \cdot n}}\right)^{1/n} = \left(\frac{1}{1 + 1,053^4}\right)^{1/2} = 0,67$

- granično naprezanje bočno-torzionog izvijanja

$$\sigma_D = \chi_p \cdot f_{lo} \cdot f_y \leq f_y \Rightarrow \sigma_D = 1,105 \cdot 0,67 \cdot 35,5 \leq 35,5 \quad ✓$$

$$\sigma_D = \underline{26,28 \text{ kN/cm}^2}$$

$$\sigma_{D,dop} = \frac{\sigma_D}{\nu} = \frac{26,28}{1,5} = \underline{17,52 \text{ kN/cm}^2}$$

$$\theta = \frac{f_y}{\sigma_D} = \frac{1}{\chi_p \cdot f_{lo}} \geq 1 \; ; \quad \theta = \frac{35,5}{26,28} = 1,35$$

* KONTROLA STABILNOSTI

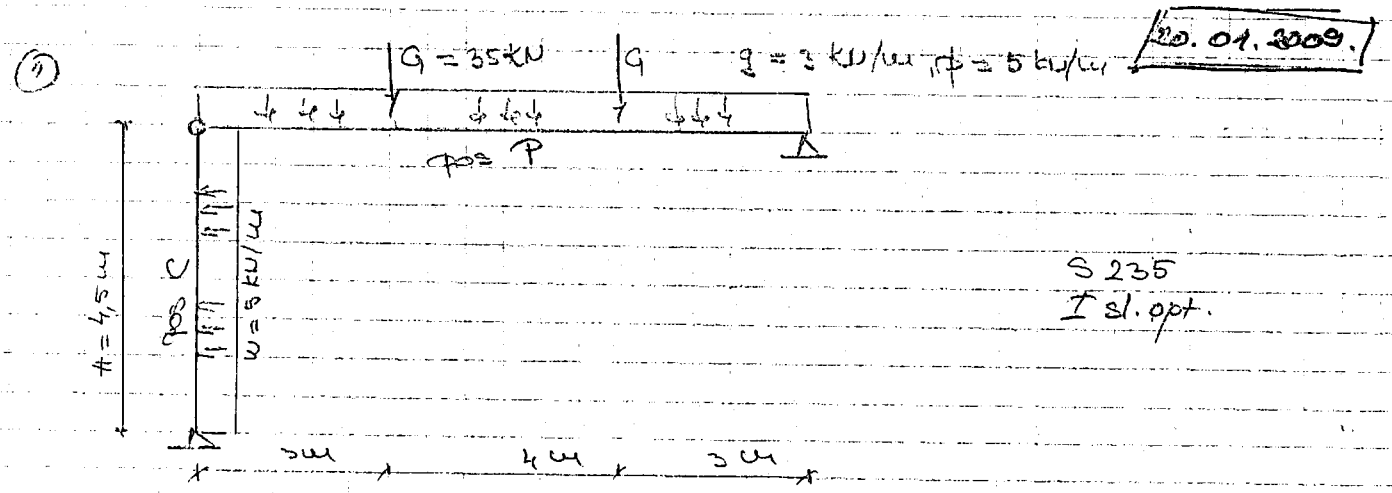
$$1,442 \cdot 1,8 + 1,35 \cdot 1,049 \cdot 11,25 \leq 17,52$$

$$18,53 \leq 17,52 \quad ↯ \Rightarrow \underline{\text{VEĆI PROFIL}}$$

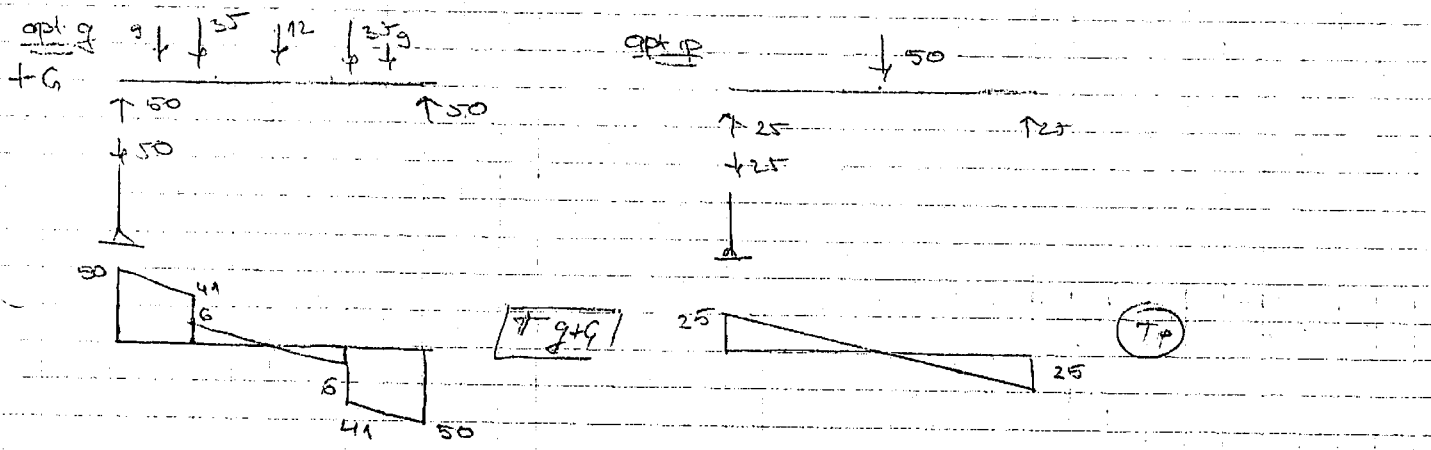
b) dimenzionirati vertikalu prema domaćim propisima. Za dop. presjek vertikale uzeti šuplji profil kvadratnog oblika.

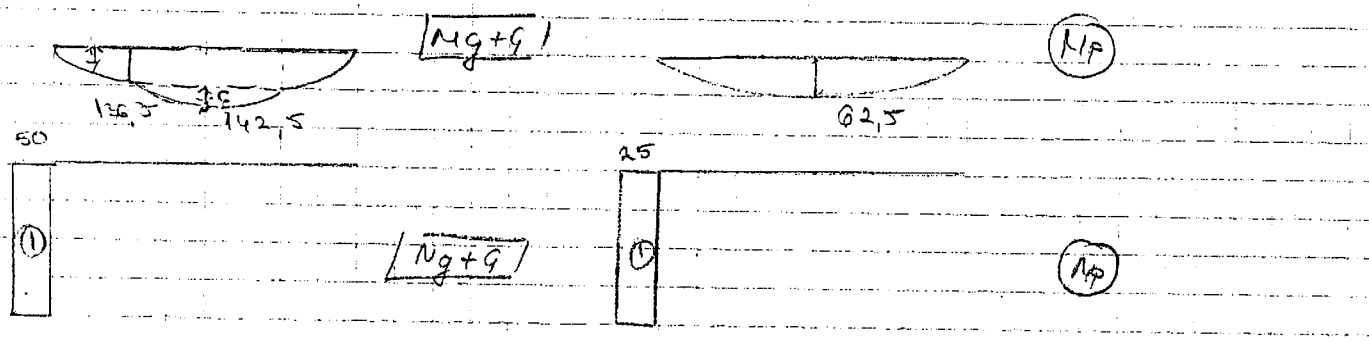
20.01.2009.

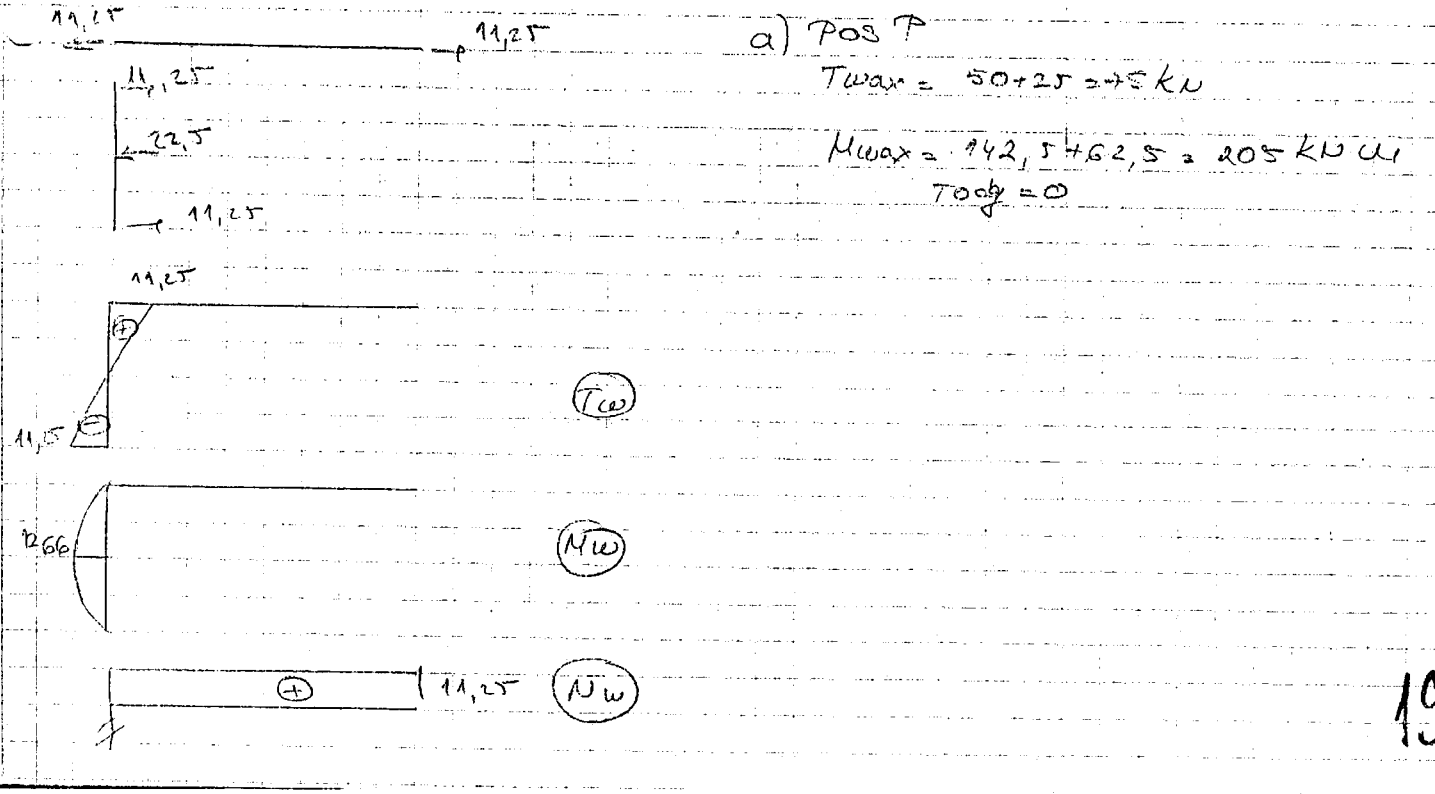
7)



S 235
I sl. opt.







a) Pos P

$T_{max} = 50 + 25 = 75\ kN$

$M_{max} = 142,5 + 62,5 = 205\ kN\,m$

$T_{odg} = 0$

g) pos 7 (obrati pažnju sta treba dimenzionisati)

$w_{dop} = \frac{l}{300} = 3,2\ cm$

S235 IPE: $\sigma_{dop} = 16\ kN/cm^2$, $\tau_{dop} = 9\ kN/cm^2$

$W_{pot} = \frac{M_{max}}{\sigma_d} = \frac{205 \cdot 100}{16} = 1281,25\ cm^3$

$A_{pot} = \frac{N_d}{\sigma_d} = \frac{11,25}{16} = 0,703\ cm^2$

HEA 400

$h = 390\ mm$, $b_f = 300\ mm$, $t_w = 11\ mm$, $t_f = 19\ mm$, $r = 27\ mm$

$A = 159\ cm^2$, $I_y = 45070\ cm^4$, $W_y = 2310\ cm^3$, $i_y = 16,8\ cm$

$I_z = 8560\ cm^4$, $W_z = 571\ cm^3$, $i_z = 7,34\ cm$, $S_y = 1280\ cm^4$

* KONTROLA NAPONA KOD EKSCENTRICNO ZATEGNUTIH ELEMENATA JUS

$\sigma_{max} = \frac{N_t}{A} + \frac{M_{max}}{W_y} = \frac{11,25}{159} + \frac{205 \cdot 100}{2310} = 8,94\ kN/cm^2 < 16\ kN/cm^2$ ✓

* $\tau_{max} = \frac{T_{max} \cdot S_y}{t_w \cdot I_y} = \frac{75 \cdot 1280}{1,1 \cdot 45070} = 1,94\ kN/cm^2 < 9\ kN/cm^2$ ✓

* $f_{max} = f_{(9)} + f_{(2)}$

$f_{(9)} = \frac{35 \cdot 300}{24 \cdot 21000 \cdot 45070} \cdot (3 \cdot 1000^2 - 4 \cdot 300^2) = 1,22\ cm$

$f_{(9)}^{prer} = 0,99$

$f_{(2)} = \frac{5 q l^4}{384 E I} = \frac{5 \cdot 0,8 \cdot 1000^4}{384 \cdot 21000 \cdot 45070} = 1,10\ cm$

$f_{max} = 2,32\ cm < 3,3\ cm$ ✓

→ zavisi samo od toga sta h je pretpostavio na početku (pogledaj 5. vežbu.

* KONTROLA UPOREDNOG NAPONA [P 7-24]

$\sigma_1 = \frac{M_{max}}{I_y} \cdot \frac{h - 2t_f}{2} + \frac{N_t}{A} = \frac{205 \cdot 100}{45070} \cdot \frac{39 - 2 \cdot 1,9}{2} + \frac{11,25}{159} = 8,08\ kN/cm^2$

$\tau_1 = \frac{T_{odg} \cdot S_{y,0}}{t_w \cdot I_y} = 0$

$\sigma_U = \sigma_1 = 8,08\ kN/cm^2 < 16\ kN/cm^2$ ✓

b) PRORAČUN EKSCENTRIČNO ZATEGNUTIH ELEMENATA PREMA EC3 [P9-4]

$$\frac{N_{t,Ed}}{N_{t,Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} \leq 1$$

$$\sigma_{x,Ed} = \frac{N_{t,Ed}}{A} + \frac{M_{y,Ed}}{W_y} \leq \frac{f_y}{\gamma_{M0}} \quad \frac{23,5}{1}$$

$M_{Ed} = 1,35 \cdot 142,5 + 1,5 \cdot 62,5 = 286,125$ kNcm
$N_{Ed} = 1,5 \cdot 11,25 = 16,875$ kN

$\sigma_{x,Ed} = \frac{16,875}{159} + \frac{286,125 \cdot 100}{2310} = 12,49$ kN/cm² < 23,5 kN/cm² ✓

+ KONTROLA GRANIČNIH STANJA NOSIVOSTI PREMA EC3 [P7-29]
- uticaj na mjestu M_{max} 4. vježba
  nad osloncem
- klasifikacija presjeka ...
- interakcija savijanja i smicanja ako je potrebno

g) glb, bočno pridržan na krajevima

$f_{dop} = 1,5$ cm ; HEA

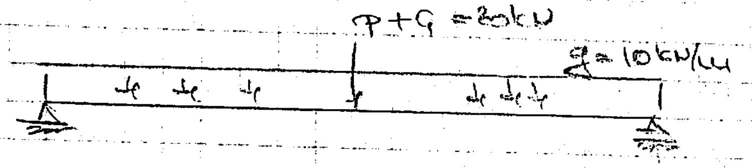
6. vježba

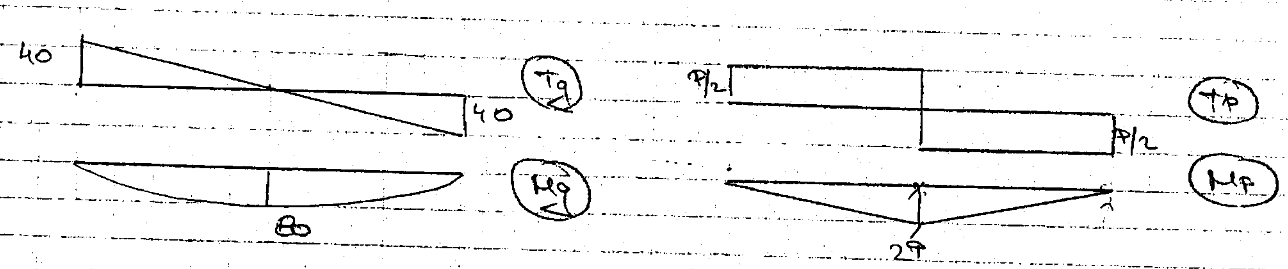
$M_{max} = 12,60$ kNm
$T_{max} = 11,25$ kN
$N = 50 + 25 = 75$ kN

- u JUSu nemamo koeficijente → provjera

- kontrola stabilnosti na bočno torziono izvijanje

① 08.06.2008.





+ usvajamo IPE

5. vežba

① $W_{pot} = \frac{M_{max}}{\sigma_{dop}} = \frac{2P + 80kNm}{\sigma_{dp}} \Rightarrow P_1$

② $\tau_{max} = \frac{T_{max} \cdot S_y}{t_w \cdot I_y} \leq \tau_{dop} \Rightarrow \frac{\left(\frac{P}{2} + 40\right) \cdot S_y}{t_w \cdot I_y} \leq \tau_{dop} \Rightarrow P_2$

③ $\sigma_u \leq \sigma_{dop} \Rightarrow \sigma_1^2 + 3\tau_1^2 = \sigma_{dop}^2$

$$\left(\frac{M_{max}}{W_y} \cdot \frac{h - 2t_f}{2}\right)^2 + 3 \cdot \left(\frac{T_{odg} \cdot S_{y0}}{t_w \cdot I_y}\right)^2 = \sigma_{dop}^2 \Rightarrow P_3$$

(P/2)

④ ugib

$$f = \frac{5}{384} \frac{q\ell^4}{EI_y} + \frac{P}{48} \frac{\ell^3}{EI_y} \leq f_{dop} \Rightarrow P_4$$

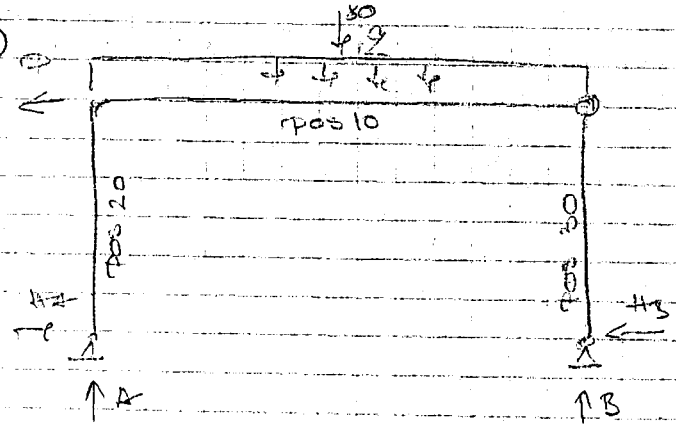
⑤ BT 1.

$$\frac{M_{max}}{W_y} < \frac{\sigma_D}{\nu} \Rightarrow P_5$$

+ usvajam min P

b) 4. vežba KONTROLA NOSIVOSTI NA SAVIJANJE I SMICANJE NOSAČA PREMA EC3

(2)



p = 5 kN

g = 25 kN

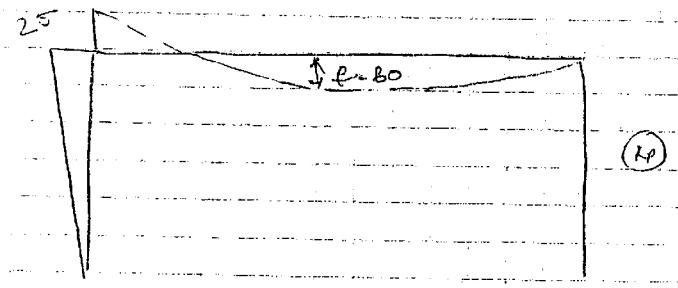
$H_A = -P$; $H_B = 0$

$M = 0$: $8 \cdot B + P \cdot 5 - 80 \cdot 4 = 0$

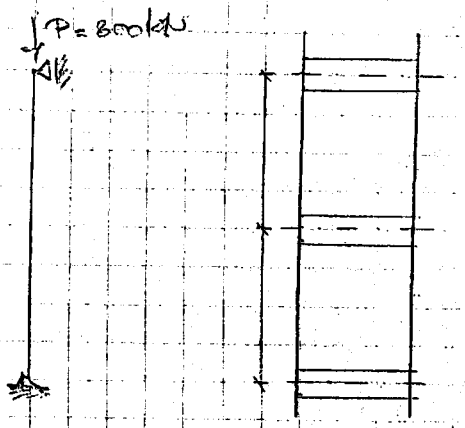
$B = \frac{320 - 25}{8} = 36{,}875$

$M_B = 0$: $80 \cdot 4 + 5 \cdot 5 - A \cdot 8 = 0$

$A = 43{,}125$



18.04.2008.

① 

S235 Isl. opt. $\sigma_{dop} = 16\,kN/cm^2$ $\lambda_0 = \lambda_1 = 92,9$

$P = 800kN$

$h = 8cm$

L 90×90×9

$A_1 = 15,5\,cm^2$
$I_{\eta 1} = I_{y1} = 116\,cm^4$
$i_{z1} = i_{y1} = 1,74\,cm$
$i_\eta = 1,76\,cm$

$a = 80cm$
$h_y = 80\,cm$
$e = 2,54\,cm$
$I_\eta = 47,8\,cm^4$

$A = 4 \cdot A_1 = 62\,cm^2$
$I_y = I_z = h \cdot \left(I_{y1} + A_1 \left(\frac{h_y}{2}\right)^2\right)$
$I_y = I_z = 56264\,cm^4$
$i_y = i_z = \sqrt{\frac{I_y}{A}} = 30,12\,cm$

① KONTROLA STABILNOSTI ŠTAPA IZVIJANJE OKO NEMATERIJALNE OSE $y-y\ (z-z)$

- određivanje ekvivalentne vitkosti

$l_y = l_z = \beta \cdot l = 1 \cdot 800cm = 800$

$\lambda_y = \frac{l_{cy}}{i_y} = \frac{800}{30,12} = 26,56$

$\lambda_f = \frac{a}{i_f} = \frac{80}{1,76} = 45,\overline{45}$ - VITKOST SAMOSTALNOG ELEMENTA $\lambda_f = \frac{a}{i_f}$ ovde $\frac{a}{i_r}$ za štap str. 665.

$\lambda_{y,eq} = \lambda_{\eta,eq} = \sqrt{\lambda_y^2 + \frac{(\omega_1)}{2} \cdot \lambda_f^2} = \sqrt{26,56^2 + \frac{7}{2} \cdot 45,\overline{45}} = 52,64$ (7 iz 662. str.)

- relativna ekvivalentna vitkost

$\bar{\lambda}_{z,eq} = \bar{\lambda}_{y,eq} = \frac{\lambda_{y,eq}}{\lambda_0} = \frac{52,64}{92,9} = 0,567$

$\alpha = 0,489$ (kriva izvijanja a)

$\beta_{z,eq} = 1 + \alpha(\bar{\lambda}_{z,eq} - 0,2) + \bar{\lambda}_{z,eq}^2$

$\beta_{z,eq} = 1 + 0,489(0,567 - 0,2) + 0,567^2 = 1,501$

$\chi_{z,eq} = \frac{2}{\left(\beta_{z,eq} + \sqrt{(\beta_{z,eq}^2 - 4\bar{\lambda}_{z,eq}^2)}\right)} = \frac{2}{(1,501 + \sqrt{1,501^2 - 4 \cdot 0,567^2})} = 0,805$

→ KONTROLA STABILNOSTI

$\sigma = \frac{N_d}{A} = \frac{800}{62} = 12,88\,kN/cm^2 < \sigma_{i,dop} = \chi_{z,eq} \cdot \sigma_{dop} = 0,805 \cdot 16 = 12,90\,kN/cm^2$

b) KONTROLA STABILNOSTI NA IZVIJANJE SAMOSTALNOG ELEMENTA NA SREDINI VISINE VIŠEDELNOG ŠTAPA

• određivanje s/o u samostalnom elementu

$N_{pl} = A \cdot f_y = 62 \cdot 24 =$

$N_{cr} = \pi^2 \cdot \frac{E I_z}{l_{iz}^2} = \frac{\pi^2 \cdot 21000 \cdot 56264}{800^2} = 18220{,}89\ kN$

$S_v = 2\pi^2 \frac{E \cdot I_f}{a^2}$ – KRUTOST VIŠEDELNOG ŠTAPA NA SMICANJE
I_f – mom. inercije u odnosu na osu 1-1 str. 665.

$S_v = 2\pi^2 \cdot \frac{21000 \cdot 49{,}8}{80^2} = 3095{,}37\ kN$

$\frac{1}{N_{cr,v}} = \frac{1}{N_{cr}} + \frac{1}{S_v} = \frac{1}{18220{,}89} + \frac{1}{3095{,}37} \Rightarrow N_{cr,v} = 2646{,}32\ kN$

$M_y = \frac{N_c \cdot f_0}{1 - \frac{\nu \cdot N_c}{N_{cr,v}}}$ — f_0 početna geometrijska imperfekcija $L/500$

$M_y = \frac{800 \cdot 800/500}{1 - \frac{1{,}5 \cdot 800}{2646{,}32}} = 2342{,}00\ kNcm$

$W_z = \frac{I_z}{y_{f,max}} = \frac{56264}{297{,}46} = 189{,}15\ cm^3$ $\quad y_{f,max} = \frac{600}{2} - 2{,}54\ cm = 297{,}46$ (e)

$y_{f,max}$ – rast. do težišta samostalnog elementa

$N_1 = \frac{N}{4} + \frac{M_z}{W_z} \cdot A_1 = \frac{800}{4} + \frac{2342{,}00}{189{,}15} \cdot 15{,}5 = 391{,}92\ kN$

• nosivost samostalnog elementa

$\bar{\lambda}_z = \frac{\lambda_z}{\lambda_v} = \frac{45{,}45}{92{,}9} = 0{,}489$

$\alpha = 0{,}489 \Rightarrow \beta_z = 1 + \alpha(\bar{\lambda}_z - 0{,}2) + \bar{\lambda}_z^2 = 1 + 0{,}489\,(0{,}489 - 0{,}2) + 0{,}489^2 = 1{,}38$

$\kappa_z = \frac{2}{\beta_z + \sqrt{\beta_z^2 - 4\bar{\lambda}_z^2}} = \frac{2}{1{,}38 + \sqrt{1{,}38^2 - 4 \cdot 0{,}489^2}} = 0{,}850$

* kontrola stabilnosti

$\sigma = \frac{N_1}{A_1} = \frac{391{,}92}{15{,}5} = 25{,}285\ kN/cm^2 < \sigma_{i,dop} = \kappa_z \cdot \sigma_{dop} = 0{,}850 \cdot 16\ kN/cm^2$

[NIJE PROŠLO, AL AJ DA ZAMISLIMO DA JESTE!]

3) KONTROLA STABILNOSTI NA IZVIJANJE SAMOSTALNOG ELEMENTA U KRAJNJEM POLJU

• uticaji u samostalnom elementu

$N_1 = \frac{N}{n} = \frac{800}{4} = 200\,kN$

$w_{max}\,U = \frac{\pi}{L} \cdot \frac{N_c \cdot w_0}{1 - \frac{N \cdot N_c}{N_{ER,U}}} = \frac{\pi}{800} \cdot 2842 = 9,197\,kN$

$M_1 = \frac{w_{max}U}{n} \cdot \frac{a}{2} = \frac{9,197}{4} \cdot \frac{80}{2} = 91,97\,kN\,cm$

• KONTROLA NAPONA U SAMOSTALNOM ELEMENTU U KRAJNJEM POLJU

$\sigma = \frac{N_1}{A_1} + \frac{M_1}{W_1} = \frac{200}{15,5} + \frac{91,97}{13,3} = 19,82\,kN/cm^2 > 16,0\,kN/cm^2$

(gde, nije prošlo!)

4) PROVERA SPOJNIH LIMOVA GG7. str.

• uticaji u spojnim limovima

$T = \frac{w_{max}U \cdot a}{h_1} = \frac{9,197 \cdot 80}{600} = 12,26\,kN$

$M = \frac{w_{max}U \cdot a}{n} = \frac{9,197 \cdot 80}{4} = 183,94\,kNcm$

* usvaja se usvojen lim 140 × 10 × 600

• kontrola napona $\sigma = \frac{M}{W} = \frac{183,94}{\frac{14^2 \cdot 1}{6}} = 5,63\,kN/cm^2$

$\tau = \frac{T}{t \cdot h} = \frac{12,26}{1 \cdot 14} = 0,876\,kN/cm^2$

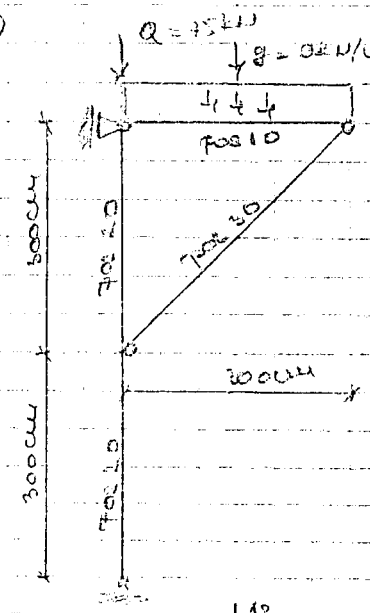
$\sigma_u = \sqrt{\sigma^2 + 3 \cdot \tau^2} = \sqrt{5,63^2 + 3 \cdot 0,876^2} = 5,83\,kN/c$ <σ

* RAM

① KONTROLA STABILNOSTI NA IZVIJANJE OKO MATERIJALNE OSE
② KONTROLA STABILNOSTI NA IZVIJANJE OKO NEMATERIJALNE OSE
③ KONTR. NA IZVIJANJE SAMOSTALNOG EL. NA SREDINI UKUPNE VISEĆINOG STAPA
④ — " — U KRAJNJEM POLJU
⑤ PROVERA SPOJNIH LIMOVA

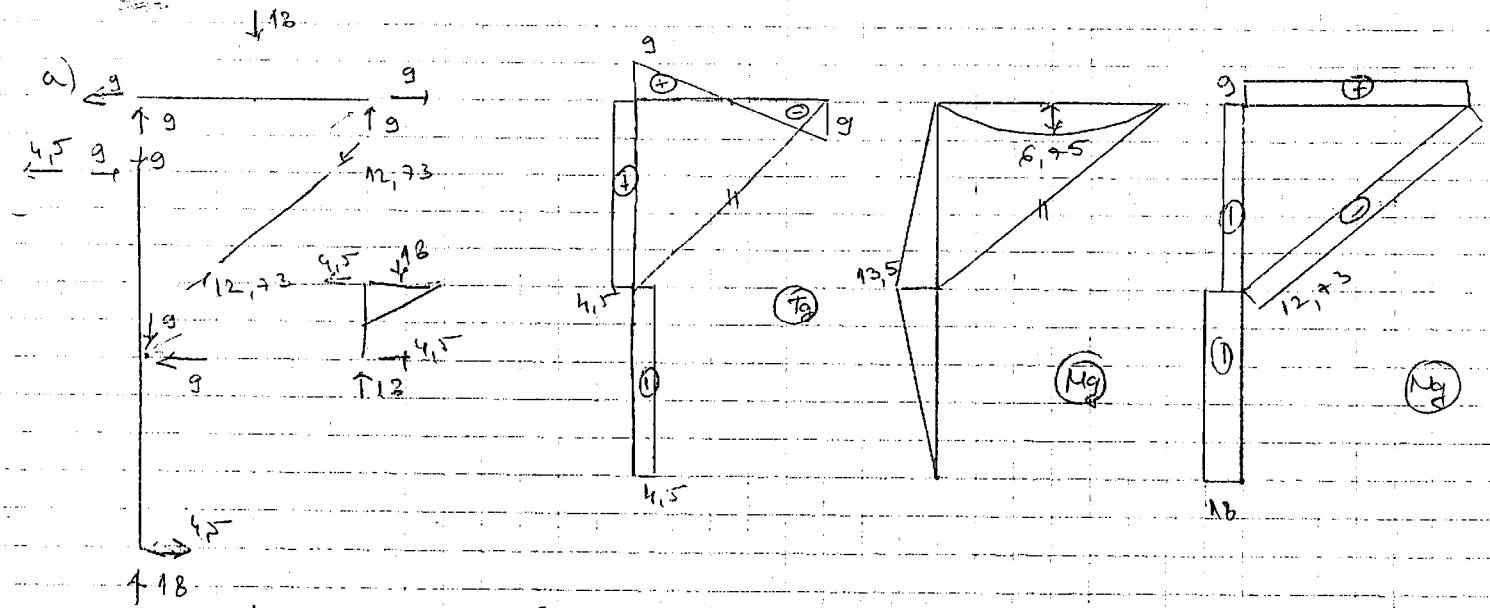
* REŠETKA (elaborat)

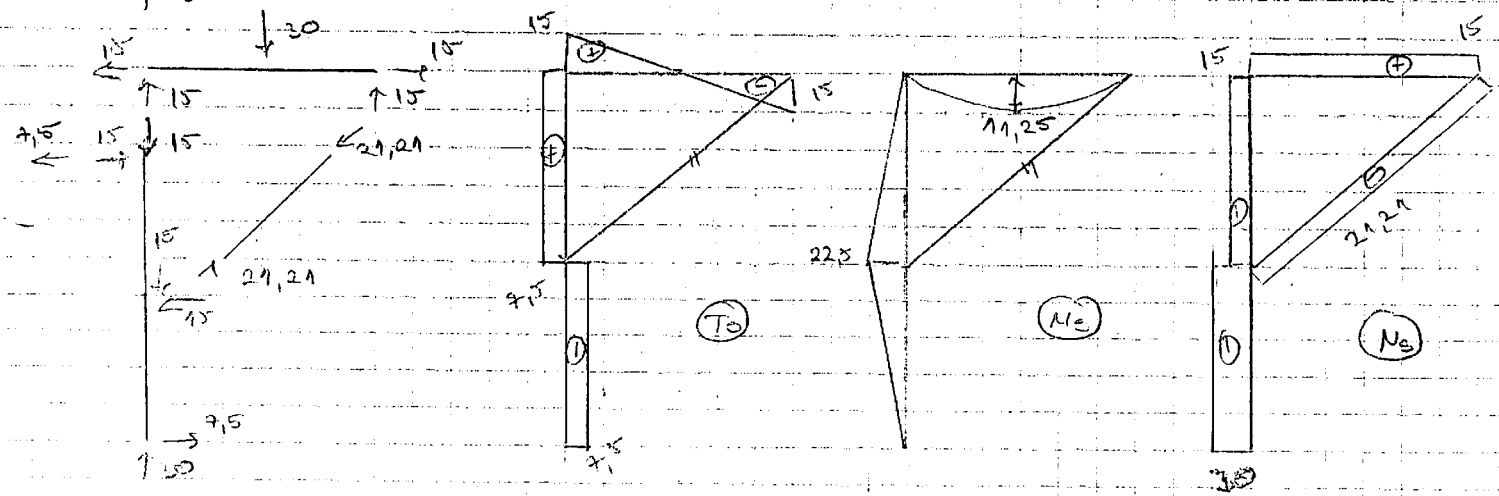
(2)

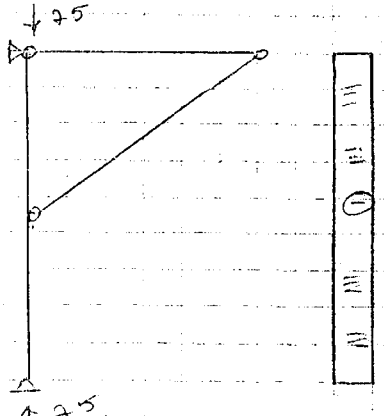


S235 } $\sigma_{dop} = 16 kN/cm^2$
I-Profil

$f_{dop} = 1 cm$
$U_{dop} = 2,4 cm$







a) pos 10 prvek EC3

S 235 } $\sigma_d = 16\ kN/cm^2$
I.st. } $\tau_d = 9\ kN/cm^2$
$t_{do} = 1\ cm$

$W_{pot} = \frac{M_{max}}{\sigma_d} = \frac{18 \cdot 100}{16} = 112,5\ cm^3$

$A_{pot} = \frac{V_t}{\sigma_d} = \frac{24}{16} = 1,5\ cm^2$

* vyhovuje IPE 200

$h = 200\ mm$ $I_y = 1940\ cm^4$ $I_z = 142\ cm^4$
$b_f = 100\ mm$ $W_y = 194\ cm^3$ $W_z = 28,5\ cm^3$
$t_w = 5,6\ mm$ $i_y = 8,26\ cm$ $i_z = 2,24\ cm$
$t_f = 8,5\ mm$
$A = 28,5\ cm^2$ $L = 12\ dm$ $S_y = 110\ cm^3$

* únosnost na ohyb vel. M

$M_{ed} = 1,35 \cdot 69 + 1,5\ 112,5 = 2598,75\ kNcm$

$V_{t,ed} = 1,35 \cdot 9 + 1,5 \cdot 15 = 34,65\ kN$

* únosnost vůči odsouvání
$V_{Ed} = V_{t,ed} = 34,65\ kN$

$$\sigma_{x,Ed} = \frac{N_{t,Ed}}{A} + \frac{M_{Ed}}{W_y}$$

$\sigma_{x,Ed} = \frac{34,65}{28,5} + \frac{2598,75}{194} = 14,61 \leq \frac{f_y}{\gamma_{M0}} = \frac{23,5}{1}\ kN/cm^2$ ✗

+ 4. věta
(dopočítat síla, zjistit...)

b) pos 30

$A_{pot} = \frac{33,94}{16} = 2,2\ cm^2$

OSU □ 120×120
$s = 7,1\ cm$
$A = 31,41\ cm^2$
$I_y = I_z = 661,7\ cm^4$
$W_y = W_z = 110,3\ cm^3$
$i_y = i_z = 4,59\ cm$

$l_{cy} = l_{cz} = 200 \cdot 0,52 = 424,26\ cm$
$\lambda_y = \frac{l_{cy}}{i_y} = 92,43$
$\bar{\lambda}_y = 0,98$ i $\alpha = 0,469$ (c kruhová)
$\beta = 1 + \alpha(\bar{\lambda} - 0,2) + \bar{\lambda}^2 = 2,34$
$\chi = \frac{2}{\beta + \sqrt{\beta^2 - 4\bar{\lambda}^2}} = 0,55$
$\sigma = \frac{N_{Ed}}{A} = \frac{33,94}{31,41} = 1,08\ kN/cm^2 \leq 0,55 \cdot 16 = 8,8\ kN/cm^2$ ✓

b) φ 26

29

$W_{pot} = \frac{M_{max}}{\sigma_d} = \frac{3600}{16} = 225\ cm^3$

$A_{pot} = \frac{(48+75)}{16} = 7,69\ cm^2$

IPE 220 ...

* kontrola napona

$\sigma_{max} = \frac{N_{cRed}}{A} + \frac{M_{max}}{W_y} \leq \sigma_d$

$\tau_{max} = \frac{T_{max} \cdot S_y}{I_y \cdot t_w} \leq \tau_d$

$f_{max} =$

?

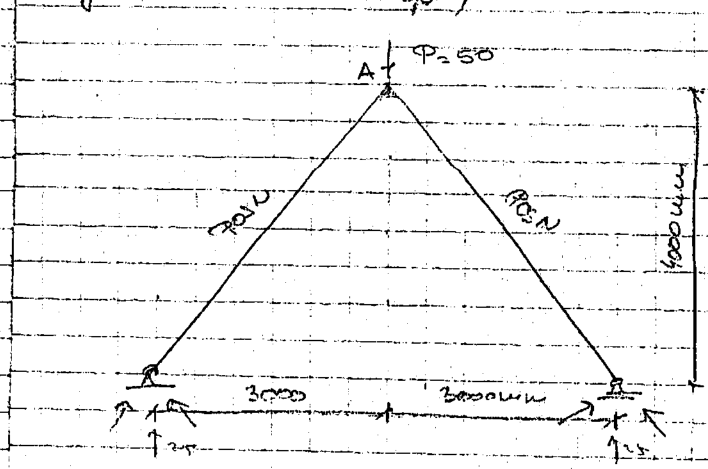
$N_{c,Red} = (95 + 9 + 15) +$

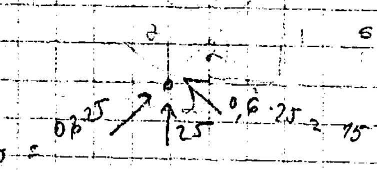
* KONTROLA EKSCENTRIČNO PRITISNUTOG ELEMENTA ...

* PROVERA NA [illegible]

Zadatak 2.

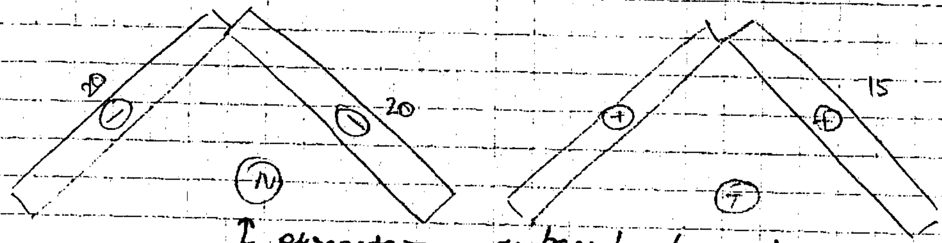
Dimenzionisati nosač (štap) prikazan na slici. Nosač je opterećen koncentrisanom silom P = 50 kN. Tačke bočnog pridržavanja nosača su u osloncima i u čvoru A. Za poprečni presek nosača usvojiti valjani IPE profil. Osnovni materijal je S235 (I sl. opt.)





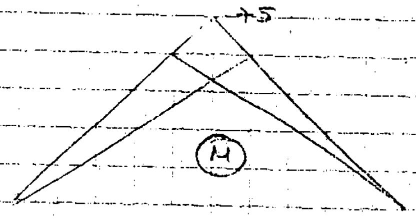
$\cos\alpha = \frac{3}{5} = 0{,}6$

$\sin\alpha = \frac{4}{5} = 0{,}8$



[ekscentrično pritisnut element]

[6 zadatak elaborat]



S235, I sl.: $\sigma_{dop} = 16\ kN/cm^2$, $\tau_{dop} = 9\ kN/cm^2$

$$W_{potr} = \frac{M_{max}}{\sigma_{dop}} = \frac{75 \cdot 10^2}{16} = 468{,}75\ cm^3$$

* Pretpostavlja se IPE 300

h = 300 mm	A = 53,8 cm²
b = 150 mm	W_y = 557 cm³
t_w = 7,1 mm	I_y = 8360 cm⁴
t_f = 10,7 mm	S_y = 314 cm³
r = 15 mm	

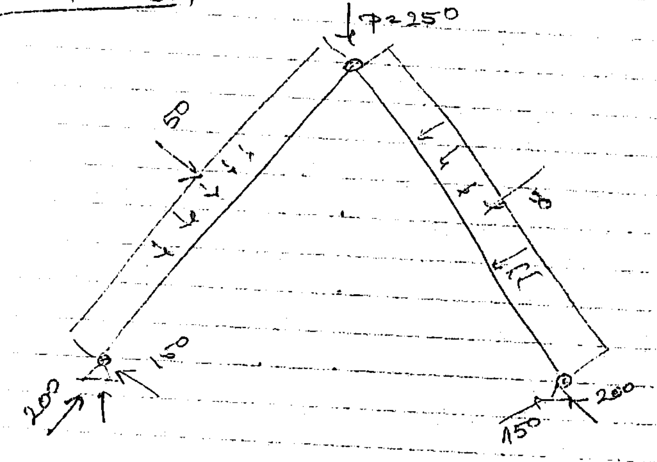
* KONTROLA NAPONA

– presek za max M

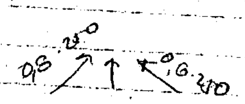
$$\sigma_{max} = \frac{M_{max}}{W_y} + \frac{N}{A} = \frac{75 \cdot 10^2}{557} + \frac{20}{53{,}8} = 13{,}83\ \frac{kN}{cm^2} < \sigma_{dop} = 16\ kN/cm^2$$

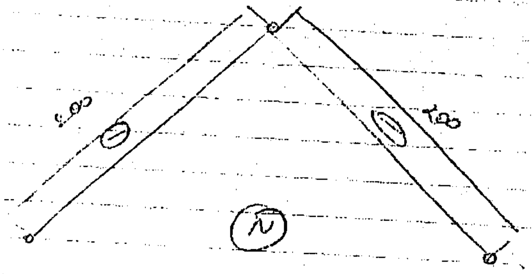
$$\tau_{max} = \frac{T_{max} \cdot S_y}{t_w \cdot I_y} = \frac{75 \cdot 314}{0{,}71 \cdot 8360} = 0{,}79 < \tau_{dop} = 9\ kN/cm^2$$

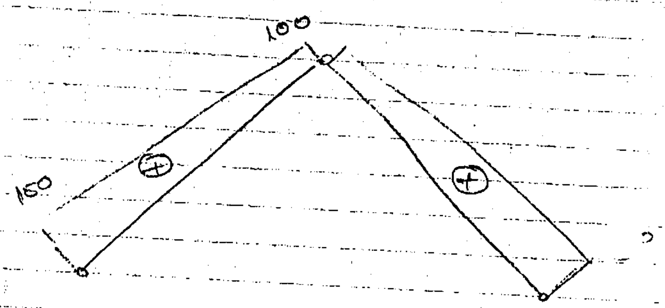
15.4.2006.

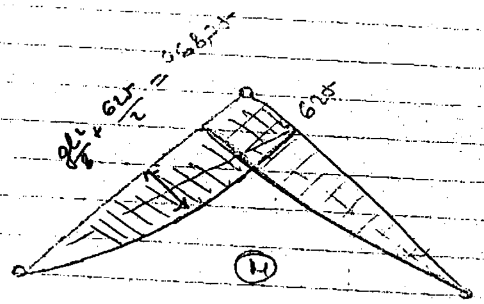


- Tačka bočnog pridržavanja iznad oslonaca, ... $\ell_y =$ $\ell_z =$





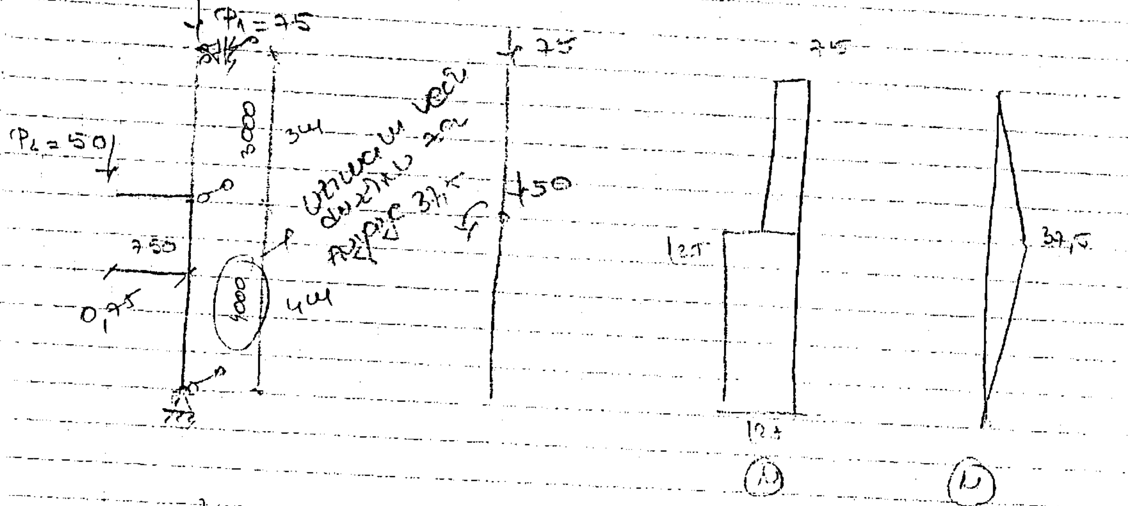




→ EKSCENTRIČNO PRITISNUT ELEMENT
6. vežba

Zadatak 2.

Dimenzionisati stub prikazan na slici. Stub je opterećen koncentrisanom silom na vrhu (P_1 = 25kN) i na konzoli (P_2 = 50kN). Stub je ... na ... vezan ... IPE profil. S235 JSt.



S235 / JSt: $\sigma_{dop} = 16 kN/cm^2$

$$W_{pot} = \frac{M_{max}}{\sigma_{dop}} = \frac{37,5 \cdot 100}{16} = 234,375 cm^3 \Rightarrow \text{pretp. IPE 270}$$

$$\sigma = \frac{N}{A} + \frac{M}{W_y} = \frac{125}{45,9} + \frac{37,5 \cdot 100}{429} = 11,46 < \sigma_{dop} = 16 kN/cm^2 \Rightarrow$$

usvajamo IPE 270 ⇒ $I_y = 5790 cm^4$; $W_y = 429 cm^3$ ...

$\sigma_{max} < \sigma_{dop}$

* Kontrola ekscentrično pritisnutog elementa [$k_n \cdot \bar{\sigma}_n + \vartheta k_{my} \cdot \sigma_{my} \leq \sigma_{dop}$]

$\sigma_N = \frac{N}{A} = \frac{125}{45,9} =$ $\bar{\sigma}_N = \frac{\sigma_N}{\sigma_{dop}} =$

$\sigma_{My} = \frac{M}{W_y} = \frac{37,5 \cdot 100}{429} =$

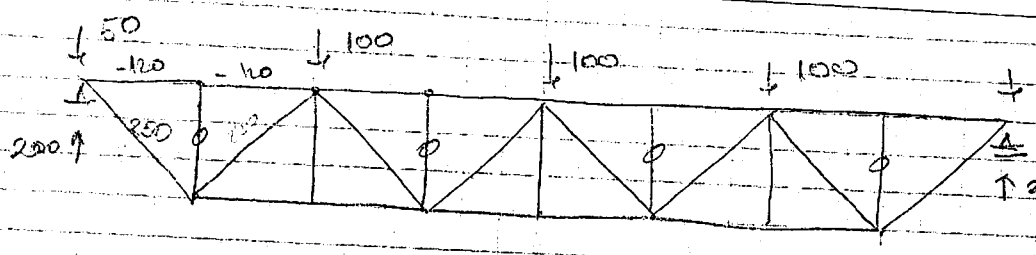
- vitkost

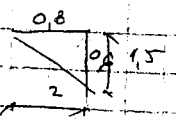
~ u ravni $\lambda_y = \frac{l_{iy}}{i_y} = \frac{l \cdot 1}{11,2} = \frac{700}{11,2} =$

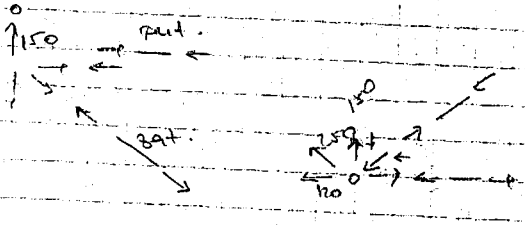
~ izvan $\lambda_z = \frac{l_{iz}}{i_z} =$

Ako treba da se uzmu bočno ... $l_{iz} = ?$; $l_{iy} = ?$

16. sept. 2002



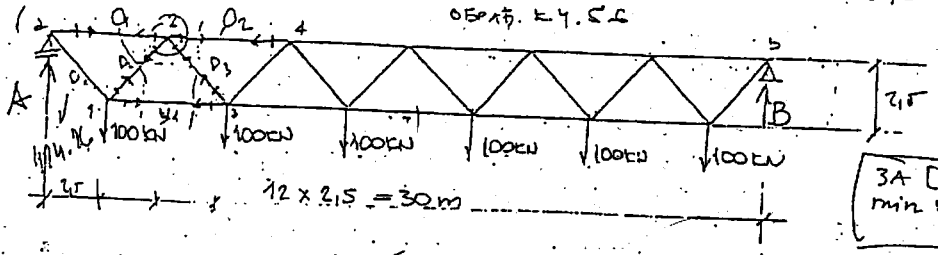




(3) : 12.XII

СО361 (Ст.от) $\sigma_{dop} = 16 \frac{kN}{cm^2}$

обрѣш. к 4.5 с



ЗА D min 50 точки

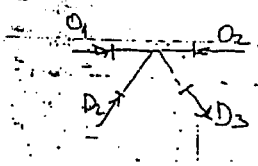
$A = 300\ kN \quad B = 300\ kN$ ✓

$\Sigma M_{(1)} = 0 \quad 2,5 \cdot A + O_1 \cdot 2,5 = 0 \Rightarrow O_1 = -A$ $\boxed{O_1 = -300\ kN}$ притиск

$\Sigma M_{(2)} = 0 \quad A \cdot 5 - 100 \cdot 2,5 - U_1 \cdot 2,5 = 0 \Rightarrow \boxed{U_1 = 500\ kN}$

$\Sigma M_{(3)} = 0 \quad 100 \cdot 2,5 - D_2 \cdot 2,5 \cdot \sqrt{2} - U_1 \cdot 2,5 = 0$ $\boxed{D_2 = -282,84\ kN}$

$\Sigma Y = 0$ $\boxed{D_3 = -D_2 = 282,84\ kN}$ затегнута



$O_2 = O_1 + (D_2 + D_3)\frac{\sqrt{2}}{2}$

$= -O_1 + D_2\sqrt{2}$

$\boxed{O_2 = 700\ kN}$ — притиснато

ЗАТЕГНУТА ДИЈАГОНАЛА (D_3) ⊥L

ПРИТИСНУТА ДИЈАГОНАЛА (D_2) ⊥

ПОЈАСНИ ШТАПОВИ ВАЛЈАНИ I ПРОФИЛ

а)

1) ЗАТЕГНУТА ДИЈАГОНАЛА $D_3 = 282,84\ kN$ ⊥L

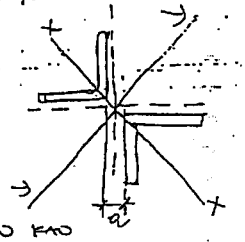
$\frac{D_3}{2A_{pot}} \le \sigma_{dop} \Rightarrow A_{pot} \ge \frac{D_3}{2\sigma_{dop}} = \frac{282,84}{2 \cdot 16} = 8,84\ cm^2$

УСВАЈА СЕ 2L 60x60x8 ($A = 9,03\ cm^2$ – површина једног профила)

2) ПРИТИСНУТА ДИЈАГОНАЛА $D_2 = 282,84\ kN$ $l_2 = 353,55\ cm$

$A_{pot} \ge \frac{D_2}{2\sigma_{dop}} = \frac{282,84}{2 \cdot 16} = 8,84\ cm^2$

$\Rightarrow \boxed{2L\ 100x100x10 \quad (A_{tot} = 19,2\ cm^2)}$



$i_1 = 1,95$ (полупр. ин. самосталног ел.)

$I_x = 560$

$i_x = 3,82$

$\boxed{I_y = ?}$ ШТА ЈЕ a у СЛИЦИ

ДА БИ СЕ ШТАП ТРЕТИРАО КАО ЗГЛОБНОСАЛНИ ТРЕБА ДА ВАЖИ $a \le 70 i_1 = 81,2$

$\frac{l_2}{4} = 88,39$

$\frac{l_2}{3} = 117,85$

$\boxed{\beta = 0,9 \rightarrow$ ЗА ⊥ | И МЕРОДАВНО ЈЕ i_x}

$l_{ix} = \beta \cdot l_2 = 0,9 \cdot 353,55 = 318,20\ cm$

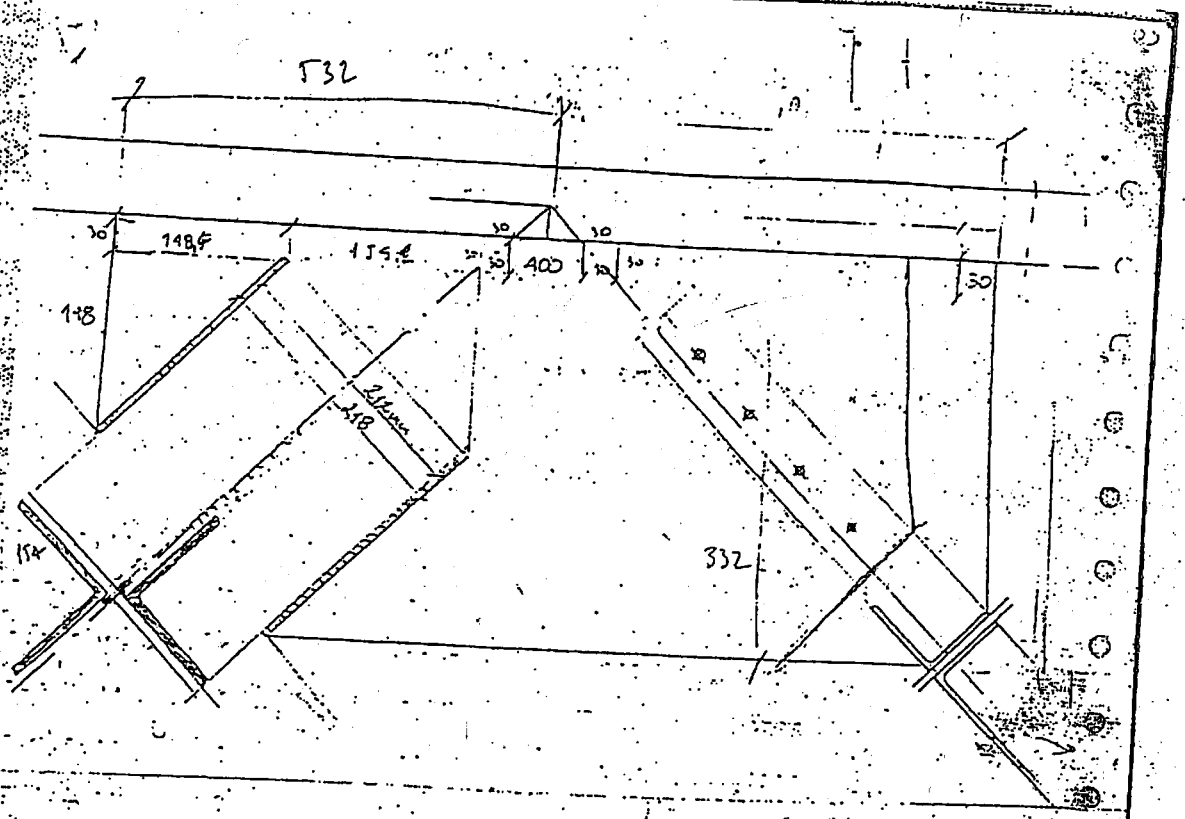
$\lambda_{ix} = \frac{l_{ix}}{i_x} = \frac{318,20}{3,82} = 83,30 = \lambda$

$\boxed{\lambda_V = 92,9 \quad \sigma_V = 24 \frac{kN}{cm^2}}$ ЗА $t \le 40\ mm$

$\boxed{\alpha = 0,189$ (КРИВА C)

$\bar{\lambda} = \frac{\lambda}{\lambda_V} = \frac{83,30}{92,9} = 0,90 > 0,2$

$\beta = 1 + \alpha(\bar{\lambda} - 0,2) + \bar{\lambda}^2 = 2,15$



$l_ш$=210 мм

Швеллер №14

$$\sigma_{ш.1} = \frac{Z}{(b_{ст} - d_1) \cdot t_{ш.1}} \leq \sigma_{доп}$$

$$= \frac{282,84}{(34,85 - 2,1) \cdot 1,2} = 7,20 < \sigma_{доп} = 16$$

$b_{ст} = b + 2 \cdot l_ш \cdot t_{g30} = 10,6 + 2 \cdot 21 \cdot t_{g30} =$

$= 34,85$

$Z =$

$=$

$\bar{\lambda} > 0,2 \Rightarrow \varkappa = \frac{2}{\beta + \sqrt{\beta^2 - 4\bar{\lambda}^2}} = 0,60$ — 2 — 34

$\sigma_{i,dop} = \varkappa \cdot \frac{\sigma_v}{\nu} = 0,45 \cdot \frac{24}{1,5} = 9,62$ ($\nu = 1,5$ ЗА ОСНОВНО ОПТ.)

$\sigma = \frac{D_3}{2A_{usv.}} = \frac{282,84}{2 \cdot 19,2} = 7,36 < \sigma_{i,dop}$

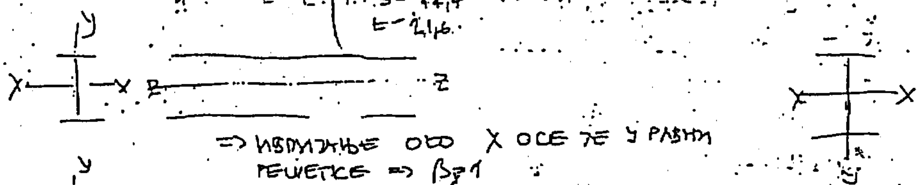
УСВАЈА СЕ 2L 100 × 100 × 10 ($A_1 = 19,2\ cm^2$)

3) ПОЈАСНИ ШТАПОВИ (ПРЕМА ВЕЋОЈ СИЛИ ⇒ $O_2 = 700$ kN ПРИТИСАК)

БИРАМО I ПРОФИЛ $\quad l_2 = 500$

$A_{pot} \geq \frac{O_2}{\sigma_{dop}} = \frac{700}{16} = 43,75\ cm^2$

⇒ I 400 { $A = 118$, $h = 400$, $b = 155$, $t.s = 14,4$, $t = 21,6$ } $\quad i_x = 15,7$, $i_y = i_{min} = 3,13$



⇒ ИЗВИЈАЊЕ ОКО X ОСЕ ЈЕ У РАВНИ РЕШЕТКЕ ⇒ $\beta_x = 1$

⇒ ИЗВИЈАЊЕ ОКО Y ОСЕ ЈЕ УПРАВНО НА РАВАН РЕШ. ⇒ $\beta_y = 0,8$

$l_{ix} = \beta_x \cdot l_2 = 1 \cdot 500\ cm = 500\ cm$

$l_{iy} = \beta_y \cdot l_2 = 0,8 \cdot 500\ cm = 400\ cm$

$\lambda_{ix} = \frac{l_{ix}}{i_x} = \frac{500}{15,7} = 31,85$

$\lambda_{iy} = \frac{l_{iy}}{i_y} = \frac{500}{3,13} = 159,74$ (~~400~~, ~~127,80~~)

$\lambda = max\{\lambda_{ix}, \lambda_{iy}\} = 127,80$

$\lambda_v = 92,9$

I ⇒ $\frac{h}{b}$ = ~~> 1,2~~ $t < 40\ mm$ ⇒ (x-x) ⇒ КРИВА A, (y-y) ⇒ КРИВА B

$\alpha = 0,339$

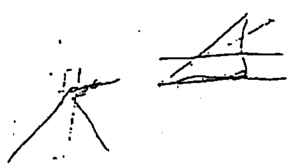
$\bar{\lambda} = \frac{\lambda}{\lambda_v} = \frac{159,74}{92,9} = 1,72 > 0,2$ (~~127,80~~, ~~1,38~~)

$\beta = 1 + \alpha(\bar{\lambda} - 0,2) + \bar{\lambda}^2 = 4,47$ (~~3,30~~)

$\varkappa = 0,273$ (~~0,59~~) $\Rightarrow \sigma_{i,dop} = 0,273 \cdot \frac{24}{1,5} = 4,37$ (~~6,29~~)

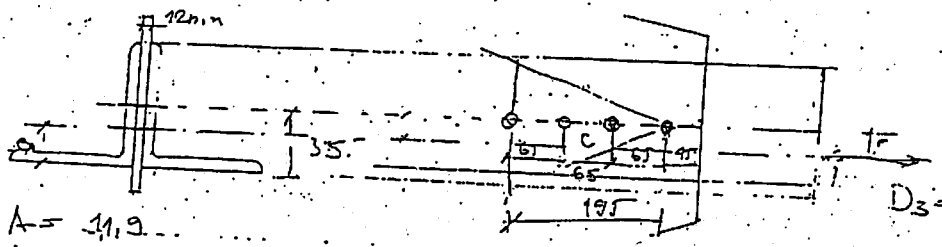
$\sigma = \frac{O_2}{A_{us}} = \frac{700}{118} = 5,93 < \sigma_{i,dop}$

Пробати I 450!



ОБРАЗЕЦ ЗАКРТЬЕВА К.Ч. 5.6

2L 70×70×9:



$D_3 = 282{,}84$

$A = 11{,}9$

$a = 80$

$s = s'$

$e_x = e_y = 2{,}05 = 20{,}5$ мм

$\sigma_{b\,dop} = 32 \frac{kN}{cm^2}$

$\tau_{dop} = 17{,}5 \frac{kN}{cm^2}$

$c = 35 - 2{,}05 = 14{,}5$

$d_{max} = \sqrt{5 \cdot t_{s\,min}} - 0{,}2 = \sqrt{5 \cdot 0{,}8} - 0{,}2 = 1{,}8$ см $(\pm 2$ мм$)$

усв. M20×1,5 с

$A_{neto} = A - 2{,}1 \cdot 0{,}8 = 10{,}07\ cm^2 \Rightarrow \sigma = \frac{D_3}{2A_{neto}} = 14{,}13 \frac{kN}{cm^2} < 16 \frac{kN}{cm^2}$

$F = \min \begin{cases} F_S = m \frac{d_1^2 \pi}{4} \tau_{dop} = 2 \cdot \frac{2{,}1^2 \pi}{4} \cdot 17{,}5 = 121{,}23\ kN \\ F_b = d_1 \cdot \Sigma t_{min} \cdot \sigma_{b,dop} = 2{,}1 \cdot 1{,}2 \cdot 32 = 80{,}64\ kN \end{cases}$

$F = 80{,}64$ kN

$n = \frac{D_3}{F} = \frac{282{,}84}{80{,}64} = 3{,}51$ $\boxed{n = 4}$

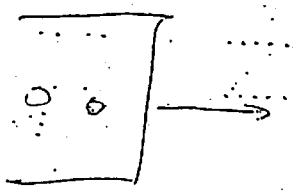
Силы у наших затяжек $F_2 = \frac{D_3}{n}$ $F_n = \frac{M \cdot r_{max}}{\Sigma r_i^2}$ $\frac{1}{4} + \frac{3}{4}$ $\frac{10}{4} = \frac{5}{2}$

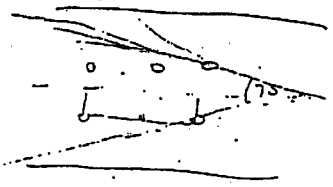
$F_R = \sqrt{20{,}71^2 + 189{,}28^2} = 20{,}71$ $= \frac{D_3 \cdot c \cdot \frac{2}{2} \cdot 6{,}5}{2 \cdot \left(6\frac{5}{2}\right)^2 + 2 \cdot \left(\frac{3}{2} 6\frac{5}{2}\right)^2}$

$5\ 20{,}71 < F$ $= \frac{282{,}84 \cdot 14{,}5 \cdot \frac{2}{2} 6{,}5}{2 \cdot \frac{5}{4} \cdot 6{,}5^2} = 189{,}28$

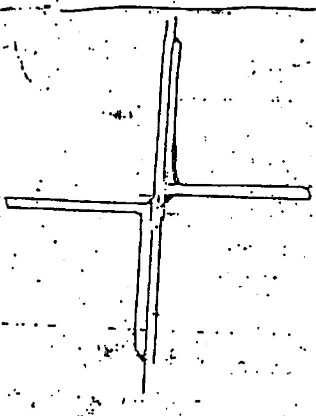
$b_{cf} = 195 \cdot \operatorname{tg} 15° = 52{,}25$ мм $= 5{,}22$ см

$\boxed{213}$





2) ВЕЗА [illegible]



$\sigma_{dop} = 12$

$V_{II} = \frac{D}{4A_š} = \frac{D}{4al} \leq \quad l = l_š - 2a$

$\Rightarrow \frac{282,84}{4 \cdot 0,3 \cdot l} \leq 12 \qquad a_š = 0,3 cm$

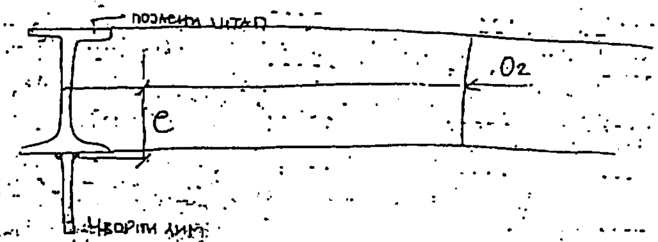
$l > \frac{282,84}{4 \cdot 0,3 \cdot 12} = 19,64 \, cm$

$l_š - 0,6 > 19,64$

$l_š > 20,24$

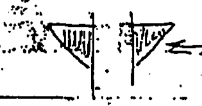
$\boxed{l_š = 21 cm}$

3) ВЕЗА ЧВОРНОГ ЛИМА ЗА ПОЈАСНИ ШТАП У ЗАВАРЕНОЈ ИЗРАДИ



$a_š = 0,3 cm$

2 шава



$M = O_2 \cdot e$

l

$n = \frac{M}{2W_š} = \frac{O_2 e}{2 \cdot \frac{al^2}{6}} = \frac{3 O_2 e}{al^2}$

$\sigma_u = \sqrt{n^2 + V_{II}^2} \leq \sigma_{dop}$

$V_{II} = \frac{O_2}{2al}$

$\sqrt{\left(\frac{3O_2 e}{al^2}\right)^2 + \left(\frac{O_2}{2al}\right)^2} \leq 12$

$\sqrt{\frac{9O_2^2 e^2}{a^2 l^4} + \frac{O_2^2}{4a^2 l^2}} \leq 12$

$n_1 = \frac{\Delta O \cdot e}{2 \cdot \frac{a \cdot l^2}{6}}$

$\frac{O_2}{al} \sqrt{\frac{9e^2}{l^2} + \frac{1}{4}} \leq 12$

$\frac{O_2}{2al} \sqrt{\left(\frac{6e}{l}\right)^2 + 1} \leq 12$

$n = \frac{6 \Delta O \cdot e}{2al^2}$

$\frac{700}{2 \cdot 0,3 l} \sqrt{\left(\frac{6 \cdot 20}{l}\right)^2 + 1} \leq 12$

$V_{II} = \frac{\Delta O}{...}$

$\frac{700}{2 \cdot 0,3 l} \sqrt{\left(\frac{120}{l}\right)^2 + 1} \leq 12$

$l = 140 \Rightarrow \sigma = 10,57$
$l = 135 \Rightarrow \sigma = 11,06$

$l_{tot} = 135 cm$

$\boxed{l_š \geq 136 cm}$