

TRANSVERZALNE SILE I MOMENTI TORZIJE

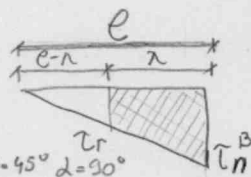
$$\tau_n^{(T)} = \frac{T_{tu}}{b \cdot z} \approx \frac{T_{tu}}{0.9 \cdot b \cdot z} ; \Delta A_a = \frac{T_{tu}}{2 \cdot b \cdot v}$$

$$\tau_n^{(M)} = \frac{M_{tu}}{2 \cdot A_{a0} \cdot \delta_0} ; \Sigma A_a = \frac{M_{tu} \cdot 0.60}{2 A_{a0} \cdot b \cdot v}$$

$$\tau_n = \tau_n^{(T)} + \tau_n^{(M)} < 5 \tau_r$$

dužina osiguranja:

$$\lambda = e \cdot \left(1 - \frac{\tau_r}{\tau_n}\right)$$



NOSIVOST UZENGUJE

$$T_{u,u} = \frac{m \cdot a_u^{(1)}}{b \cdot e_u} \cdot b \cdot v \cdot (\cos \alpha + \sin \alpha \cdot \cot \theta)$$

$$C_{u,max} = \frac{m \cdot a_u^{(1)}}{b \cdot T_{u,max}} \cdot b \cdot v \cdot (\cos \alpha + \sin \alpha \cdot \cot \theta)$$

$$BAB \Rightarrow C_{u,max} = \min \left\{ \frac{25 \text{ cm}}{b}, \frac{1}{12} \right\}$$

$a_u^{(1)}$ - u funkciji od e_u

$$a_{u,T}^{(1)} = \frac{e \cdot \tau_{ru}^{(T)}}{m \cdot b \cdot v} \cdot e_u$$

$$a_{u,MT}^{(1)} = \frac{M_{tu}}{2 A_{a0} \cdot b \cdot v} \cdot e_u \Rightarrow a_{u,T}^{(1)} + a_{u,MT}^{(1)}$$

SPOLJAŠNJA uzengija (M_{tu}, T)

$$a_{u,sp}^{(1)} = \frac{a_{u,T}^{(1)}}{2} + a_{u,MT}^{(1)}$$

UNUTRAŠNJA (SAMO T sile)

$$a_{u,un}^{(1)} = \frac{a_{u,T}^{(1)}}{2}$$

- 1) $\tau_n < \tau_r \Rightarrow$ nije potrebno osiguranje $\tau_{ru} = \frac{3}{2} \cdot (\tau_n - \tau_r)$
- 2) $\tau_r < \tau_n < 3 \tau_r \Rightarrow$ osiguranje na redukovanu silu $T_{ru} = 0$ $M_{ru} = 0$ $\tau_{ru} = \tau_n$
- 3) $3 \tau_r < \tau_n < 5 \tau_r \Rightarrow$ osiguranje $T_{ru} = 0$ $M_{ru} = 0$ $\tau_{ru} = \tau_n$

$$T_{ru} = \frac{1}{2} \cdot (3 \tau_r - \tau_n) \cdot b \cdot z$$

HB	15	20	25	30	35	40	45	50	55	60
τ_r	0,6 MPa	0,8 MPa	0,95 MPa	1,10 MPa	1,20 MPa	1,30 MPa	1,40 MPa	1,50 MPa	1,55 MPa	1,60 MPa

$C_{u,usu} < C_{u,max}$, Ako je C_u vrlo malo možemo:

- povećati 1) prečnik uzengije $a_u^{(1)}$
- 2) sečnost uzengije m ($m = \{2, 4, 6\}$)
- 3) primeniti koso povijene profile

MINIMALNE VERTIKALNE uzengije! ($\mu = 0,2\%$)

$$\mu_{uz} = \frac{m \cdot a_u^{(1)}}{b \cdot e_u} \geq 0,2\% \Rightarrow e_u = \frac{m \cdot a_u^{(1)}}{b \cdot \mu_{uz,min}}$$

$$A_{b0} = b_0 \cdot d_0 = (b - 2a) \cdot (d - 2a) \quad \left[a = a_0 + \phi_4 + \frac{\phi}{2} \right]$$

$$\delta_0 = \frac{d_m}{8} = \frac{\min(b_0, d_0)}{8} = \frac{\min((b - 2a), (d - 2a))}{8}$$

$$O_{b0} = 2 \cdot (b_0 + d_0)$$

$$\tau_n^{(T)} = \frac{T_{tu}}{0,9 \cdot b \cdot b}$$

$$\Delta A_a = \frac{T_{tu}}{2 \cdot b \cdot v}$$

$$\tau_n^{(M)} = \frac{M_{tu}}{2 \cdot A_{a0} \cdot \delta_0}$$

$$\Sigma A_a = \frac{M_{tu} \cdot 0.60}{2 A_{a0} \cdot b \cdot v}$$

UKUPNA ARMATURA $A_{a,u} = A_a + \Sigma A_a$ - se dodaje na A_a od MOMENTA SAVIJANJA

ovde ne ide redukovana sila

$\Delta A_a = 0$
Ako je špic MOMENTA SAVIJANJA
 $\Delta A_a = -$

• KOSO POVIJENI PROFILI (obavezno uzengije (minimalne) + koso povijeni)

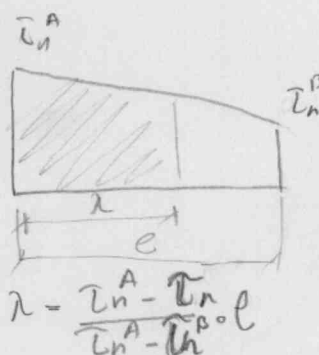
τ_n - isto kao za T sile $T_{u,u}$ = usvajam nosivost uzengija (obično minimalne)

$$x_k = \lambda \cdot \left(1 - \frac{\tau_{u,u}}{\tau_{ru}}\right) \Rightarrow H_{vu,k} = \frac{\tau_{ru} - \tau_{u,u}}{2} \cdot x_k \cdot b \xrightarrow{\alpha_k = 45^\circ} A_{ak} = \frac{H_{vu,k}}{b \cdot v \cdot (\cos \alpha + \sin \alpha \cdot \cot \theta)}$$

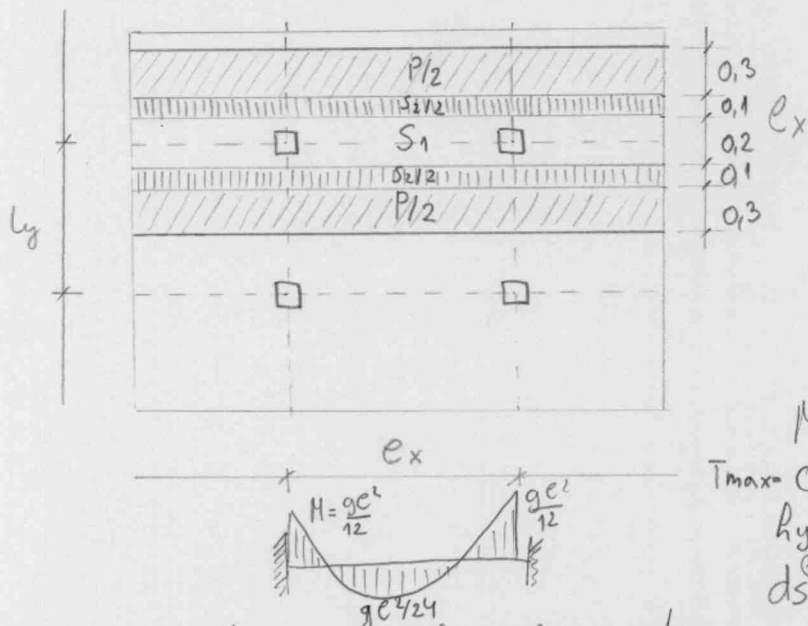
• REDUKCIJA SILE ZA $\tau_r < \tau_n < 3 \tau_r$

$$T_{ru} = T_u - T_{Gu} \quad T_{Gu} = \frac{1}{2} \cdot (3 \tau_r - \tau_n) \cdot b \cdot z$$

$$M_{ru} = M_{tu} - M_{Gu} \quad M_{Gu} = (3 \tau_r - \tau_n) A_{b0} \delta_0$$



$$\lambda = \frac{\tau_n^A - \tau_n^B \cdot e}{\tau_n^A - \tau_n^B}$$



NEGATIVNI MOMENTI:

$$M^{S_1} = 2,14$$

$$M^{S_2} = 1,44$$

$$M^P = 0,54$$

POZITIVNI MOMENTI:

$$M^{S_1} = M^{S_2} = 1,254$$

$$M^P = 0,844$$

$$M_u^{S_1} = 1,6M^{S_1} + 1,8M^{S_2}$$

$$T_{max} = Q = G + P = g \cdot l_x l_y + p \cdot l_x l_y$$

$$h_y = \dots \quad h_x = \dots \quad h_{sr} = \frac{h_y + h_x}{2}$$

$$ds = \sqrt{\frac{4b \cdot d}{\pi}} \Rightarrow d_{kp} = ds + h_{sr}$$



*) Ako su \$d > 1,5b\$ u formulu za \$ds\$ se unosi \$d_{max} = 1,5b\$, bez obzira ako je \$d\$ znatno veće od \$b\$

$$\tau_1 = 1,3 \cdot \sigma_a \cdot \sqrt{\mu} \quad \sigma_a = 1,0 - GA$$

$$\tau_2 = 0,45 \cdot \sigma_a \cdot \sqrt{\mu} \quad \sigma_a = 1,3 - RA$$

$$\sigma_a = 1,4 - MA$$

$$M_u^{S_1}(x), M_u^{S_2}(y) \Rightarrow M_u^{S_2} = \frac{M_u^{S_1}}{1,5} \Rightarrow A_{a1}^{S_1}(x, y) \Rightarrow K = \frac{A_{min}}{\sqrt{\frac{M^{S_1} \cdot 100}{f_b \cdot 100}}}$$

usvojim \$A_{a1}^{S_1}, A_{a2}^{S_2}\$ u \$x, y\$ pravcu \$A_a^{S_2}(x, y) \Rightarrow\$

$$M_x = \left(\frac{A_{a1}^{S_1}}{b_x} + \frac{A_{a2}^{S_2}}{b_x} \right) \cdot 0,5 \quad M_y = 0,5 \cdot \left(\frac{A_{a1}^{S_1}}{b_y} + \frac{A_{a2}^{S_2}}{b_y} \right)$$

$$\mu = \frac{M_x + M_y}{2} \Rightarrow 0,5 \leq \mu \leq 1,5$$

$$O_{kp} = d_{kp} \cdot \pi$$

$$\tau = \frac{T_{max}}{O_{kp} \cdot h_{sr}}$$

$$\tau_1 = \frac{2}{3} \cdot \tau_1 \cdot \tau_a$$

$$\tau_2 = \tau_2 \cdot \tau_b$$

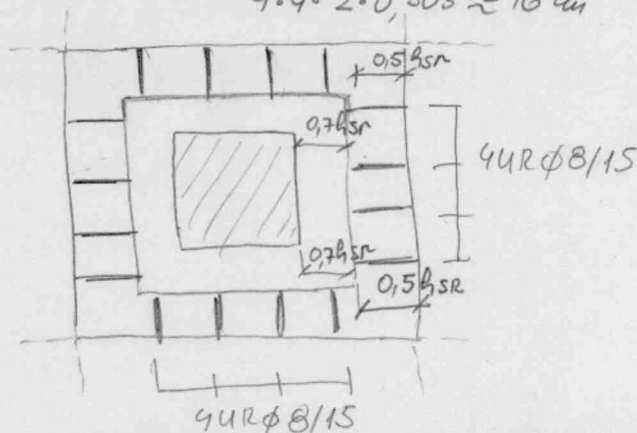
① \$\tau < \tau_1\$
Nije potrebno OSIGURANJE ARM.

② \$\tau_1 < \tau < \tau_2\$
OSIGURANJE ARM.

③ \$\tau > \tau_2 \Rightarrow\$ povećati \$d_p\$

$$\textcircled{2} \Rightarrow A_a = \frac{0,75 \cdot T_{max}}{\frac{\sigma_v}{1,8}} = \frac{1,35 \cdot T_{max}}{\sigma_v} \quad \left[\text{Npr. } A_a = 12,15 \text{ cm}^2 \Rightarrow \text{usv. } 4 \times 4 \text{ UR } \phi 8/15 \right]$$

MB	15	20	30	40	50	60
\$\tau_a\$	0,5	0,6	0,8	1,0	1,1	1,2
\$\tau_b\$	1,5	1,8	2,2	2,6	3,0	3,4



PRAVOUGAONI PRESECI

JEDNOSTRUKO ARMIRANI - VEZANO DIMENZIONISANJE $[M_u, f_c, f_y, b, d \Rightarrow A_{a1} = ?]$

$$M_{u1} = \sum \sigma_{u1} \cdot H_i \quad N_{u1} = \sum \sigma_{u1} \cdot N_i \quad M_{au} = M_u + N_u \cdot \left(\frac{d}{2} - a_1\right) \quad N_u = \begin{cases} + \text{PRITISAK} \\ - \text{ZATEZANJE} \end{cases}$$

pretpostavka $a_1 = (0,05 \div 0,15) d \Rightarrow h = d - a_1$

$$K = \frac{h}{\sqrt{\frac{M_{au}}{b \cdot f_c}}} \Rightarrow \text{TABLICA} \quad \begin{cases} K > 1,719 \Rightarrow \text{jednostruko armiranje} \\ K < 1,719 \Rightarrow \text{dvostruko armiranje} \end{cases} \quad A_{a1} = \bar{\mu} \cdot \frac{b \cdot h \cdot f_c}{100 \cdot f_y} - \frac{N_u}{f_y}$$

PROVERA $a_{1st} \Rightarrow h_{1st} \approx h$ pretpostavljeno (usled velikih odstupanja raditi ponovo) ili postaviti drugačije armature

DVOSTRUKO ARMIRANJE - VEZANO DIMENZIONISANJE $\epsilon_{a1} < 3\%$

usvajamo $\epsilon_{a1} \geq 3\%$ najčešće je to $\epsilon_{a1}^* = 3\%$ $\bar{\mu}^* = 43,590\%$ $K^* = 1,719$ $J^* = 0,776$

$$M_{bu} = \left(\frac{h}{K^*}\right)^2 \cdot b \cdot f_c \Rightarrow \Delta M_u = M_u - M_{bu} \Rightarrow A_{a2} = \frac{\Delta M_u}{(h - a_2) f_y} \quad A_{a1} = \bar{\mu}^* \cdot \frac{b \cdot h \cdot f_c}{100 \cdot f_y} + A_{a2} = \frac{M_{bu}}{J^* \cdot h \cdot f_y} + A_{a2}$$

JEDNOSTRUKO ARMIRANI PRESECI - SLOBODNO DIMENZIONISANJE $[M_u, f_c, f_y, b \Rightarrow d, A_a = ?]$

$$M_u = \sum \sigma_{u1} \cdot H_i \Rightarrow \text{usvajam deformacije } \epsilon_B / \epsilon_a \Rightarrow \text{veće } \epsilon_B \Rightarrow \text{preseki manje visine sa većom količinom armature}$$

$$h = K \cdot \sqrt{\frac{M_u}{b \cdot f_c}} \Rightarrow A_a = \bar{\mu} \cdot \frac{b \cdot h \cdot f_c}{100 \cdot f_y} = \frac{M_u}{z \cdot f_y} \Rightarrow a_{1st} \Rightarrow d = h + a_{1st} \Rightarrow d_{usv} \text{ (Broj deljiv sa 5)}$$

Ako imamo M_u i $N_u \Rightarrow$ usvajam $\epsilon_a / \epsilon_B \Rightarrow$ iterativni postupak računanja h

$$M_{au} = M_u + N_u \cdot \left(\frac{d}{2} - a_1\right) \Rightarrow h = K \cdot \sqrt{\frac{M_{au}}{b \cdot f_c}} \quad \begin{cases} \text{I KORAK } M_{au}^I = M_u \Rightarrow h^I = K \cdot \sqrt{\frac{M_{au}^I}{b \cdot f_c}} \Rightarrow d^I = a_1 + h^I \\ \text{II KORAK } M_{au}^{II} = M_u + N_u \cdot \left(\frac{d^I}{2} - a_1\right) \Rightarrow h^{II} = K \cdot \sqrt{\frac{M_{au}^{II}}{b \cdot f_c}} \Rightarrow d^{II} = a_1 + h^{II} \end{cases}$$

$$A_a = \bar{\mu} \cdot \frac{b \cdot h \cdot f_c}{100 \cdot f_y} - \frac{N_u}{f_y} \Rightarrow a_{1st} \Rightarrow d = a_{1st} + h \Rightarrow d_{usv}$$

DVOSTRUKO ARMIRANJE DODATNI USLOVI * ALO SE KOD PRORACUNA SLOŽENOG SAVIJANJA DOBIJE SLEDEĆE:

- $A_{a2} \leq A_{a1} \Rightarrow$ zategnuta i pritisnuta ZONA se armiraju sračunatim površinama A_{a1} i A_{a2}
- $A_{a1} \leq A_{a2} \leq 1,5 A_{a1} \Rightarrow$ obe zone se armiraju simetrično sa srednom vrednošću A_{a1} i A_{a2} (može i uz pomoć D.I.)
- $A_{a2} \geq 1,5 A_{a1} \Rightarrow$ preseke se armiraju simetrično a potrebna A_a se usvaja pomoću DIJAGRAMA INTERAKCIJE

MOMENT LOMA PRAVOUGAONOG PRESEKA * $[M_u = ? \text{ nije } M_{au}]$

D.I. = odnos $a_1/d =$...
simetrično raspoređena armatura i
je odnos drugačiji.
NAJ $\rightarrow \bar{\mu}$ daje ukupnu armaturu
BAG $\rightarrow \bar{\mu}_1$ daje A_a zategnute armature

$$\textcircled{1} \sum N = 0 \quad D_{bu1} + D_{au} - 2z_u - N_u = 0$$

$$S \leq 0,259 = 7127 \Rightarrow \epsilon_{a1} = 10\% \quad \epsilon_B = \frac{S}{1-S} \cdot \epsilon_{a1}$$

$$S \geq 0,259 = 7127 \Rightarrow \epsilon_B = 3,5\% \quad \epsilon_{a1} = \frac{1-S}{S} \cdot \epsilon_B$$

$$\Delta B = \frac{\epsilon_B \cdot (6 - \epsilon_B)}{12} \leq \epsilon_B \leq 2\% \quad \Delta B = \frac{3\epsilon_B - 2}{3\epsilon_B} \leq 2\% \leq \epsilon_B \leq 3,5\%$$

$$D_{bu} = \Delta B \cdot b \cdot x \cdot f_c = \Delta B \cdot b \cdot s \cdot h \cdot f_c \quad [S = x/h]$$

$$\epsilon = \frac{x - a_2}{x} \cdot \epsilon_B \Rightarrow \sigma_{a2} = \epsilon_a \cdot \epsilon_{a2} \leq \sigma_y \Rightarrow D_{au} = A_{a2} \cdot \sigma_{a2}$$

$$\sigma_{a1} = \epsilon_a \cdot \epsilon_{a1} \leq \sigma_y \Rightarrow 2z_u = A_{a1} \cdot \sigma_{a1}$$

$$\textcircled{2} z_u = h - \eta \cdot x = h(1 - \eta \cdot S) \quad \eta = \frac{8 - \epsilon_B}{4(6 - \epsilon_B)} \leq \epsilon_B \leq 2\%$$

$$\textcircled{3} \sum M_{a1} = 0: D_{bu} \cdot 2B + D_{au} \cdot (h - a_2) = M_{au} \Rightarrow \underline{M_u} = M_{au} - N_u \cdot \left(\frac{d}{2} - a_1\right)$$

ZA JEDNOSTRUKO ARMIRANE PRAVOUGAONE PRESEKE [zanemariti pritisnutu armaturu $\Rightarrow A_{a2} = 0$]

$$A_{a1} = \bar{\mu}_1 \cdot \frac{b \cdot h \cdot f_c}{100 \cdot f_y} - \frac{N_u}{f_y} \Rightarrow \bar{\mu}_1 = \Delta B \cdot S = \frac{A_{a1} \cdot \sigma_y + N_u}{b \cdot h \cdot f_c}$$

$$K = \frac{h}{\sqrt{\frac{M_{au}}{b \cdot f_c}}} \Rightarrow M_{au} = \left(\frac{h}{K}\right)^2 \cdot b \cdot f_c \Rightarrow M_u = M_{au} - N_u \cdot \left(\frac{d}{2} - a_1\right) = \left(\frac{h}{K}\right)^2 \cdot b \cdot f_c - N_u \cdot \left(\frac{d}{2} - a_1\right)$$

DODATNE NAPOMENE:

- kod ekscentrično pritisnutih preseka se usvaja "manje" a_1 je je potrebno manje armature

- Najveću površinu armature A_{a1} dobijamo usled kombinacije uticaja M_u i $2z_u$, a najmanju A_{a1} za M_u i N_u

- za pritisnutu armaturu A_{a2} merodavna je kombinacija sa što većom silom pritiska N_u .

$$S_u = 1,6 S_g + 1,8 S_p = 10\% \leq \epsilon_a \leq 3\% \quad \begin{cases} S_u = 1,3 S_g + 1,5 S_p + 1,3 S_a & \epsilon_a \in [0,0] \\ S_u = 1,5 S_g + 1,8 S_p + 1,5 S_a & \epsilon_a \geq 0 \end{cases} \quad \begin{cases} S_u = 1,0 S_g + 1,8 S_p & \text{ili } S_u = 1,0 S_g + 1,5 S_p + 1,3 S_a \\ S_u = 1,2 S_g + 2,1 S_p & \text{ili } S_u = 1,2 S_g + 1,8 S_p + 1,5 S_a \end{cases} \quad \begin{cases} \text{POVOLJNO} \\ \text{STABLO} \\ \text{OPTEREĆENJE} \end{cases}$$

$$S_u = 1,9 S_g + 2,1 S_p = \epsilon_a \geq 0,7$$

!!! ulimaju se uvek isti $M_u = 1,0 M_g + 1,8 M_p$
koeficijenti za M_u i N_u $N_u = 1,0 N_g$!!!

- ZAŠTITNI SLOJEVI ARMATURE
- $a_{01} = 2,0 \text{ cm}$ - slabog agresivnog
- $a_{02} = 2,5 \text{ cm}$ - umerenog uslovi
- $a_{03} = 3,5 \text{ cm}$ - jako agresivni

MINIMALNA ČISTA RASTOJANJA
SIPKI ARMATURE:
 $\epsilon_H > 5 \text{ cm}$ (3 cm)
 $\epsilon_V > 3 \text{ cm}$

[cm]

T PRESECI

$$B = \min \left\{ \begin{array}{l} B + 0,25 \cdot \frac{e_0}{e} \\ B + 20 \cdot dp \end{array} \right\}$$

$$\text{ili } B = \min \left\{ \begin{array}{l} B_1 + B + \frac{0,25}{3} \cdot e_0 \\ B_1 + B + B \cdot dp \\ e/2 \end{array} \right\}$$

B - KALKULISANA ŠIRINA PLOČE
 e_0 - RASTOJANJE NULTIH TAČAKA SA DIJAGRAMA
 NA DELU GDE JE PLOČA PRITISNUTA
 e - OSOVINSKO RASTOJANJE REBRA - FIZIČKI
 RASPOLOŽIVA ŠIRINA PLOČE ZA JEDNO REBRO

- ① Ako je ploča pritisnuta a neutralna linija u rebru \Rightarrow radi se proračun za T presek
 - ② Ako je ploča zategnuta \Rightarrow radi se proračun za pravougaoni presek širine B
 - ③ Ako je ploča pritisnuta a neutralna linija u ploči \Rightarrow radi se proračun za pravougaoni presek širine B
- PRORAČUN T (ili Γ) PRESEKA SE RADI U ZAVISNOSTI OD ODNOSA B/e
- $B/e > 5 \Rightarrow$ sprovodi se uprošćeni postupak (zanemaruje se nosivost rebra - konstantan napon pritiska po ploči)
 - $B/e \leq 5 \Rightarrow$ sprovodi se tačan postupak