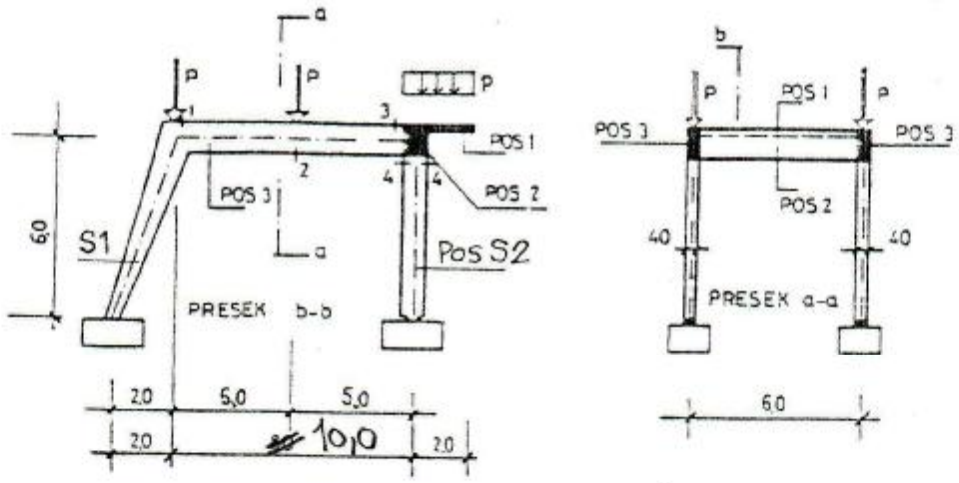
10

GRAĐEVINSKI FAKULTET U BEOGRADU
Odsek za konstrukcije
BETONSKE KONSTRUKCIJE 1
TEORIJA BETONSKIH KONSTRUKCIJA

pismeni ispit
22.08.1992.g.



Za konstrukciju prikazanu na skici potrebno je:

1. Dimenzionisati ploču **POS 1.** Za usvojenu debljinu i raspored armature sračunati srednje rastojanje i karakterističnu širinu prslina, kao i maksimalni ugib kraja konzole (nije potrebno voditi računa o dugotrajnom dejstvu stalnog opterećenja). U slučaju prekoračenja dopuštene vrednosti ugiba, komentarisati.

2. Sračunati i nacrtati dijagrame presečnih sila za POS 2 (b/d = 60/80 cm) i dimenzionisati je prema sračunatim uticajima.

3. Izvršiti analizu opterećenja za ram POS 3, POS S1, POS S2 i nacrtati dijagrame uticaja od stalnog i povremenog opterećenja. Pri proračunu statičkih uticaja usvojiti *EJ = const.* po svim štapovima.

4. Dimenzionisati POS 3 (40/100 cm) i stubove POS S1 (40/60 cm) i POS S2 (40/80 cm) u karakterističnim presecima prema *M, N, T* sračunatim u prethodnoj tački.

5. Nacrtati u približnoj razmeri plan armature rama i prikazati karakteristične poprečne preseke.

Podaci za proračun:

p = 15.0 kN/m² **MB 35**

P = 400.0 kN **RA 400/500**

1.

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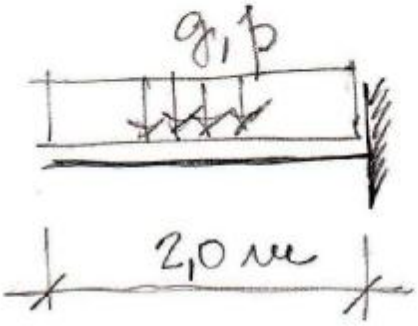
Podaci za proračun:

$p = 15.0\ kN/m^2$	***MB* 35**
$P = 400.0\ kN$	***RA* 400/500**

POS 1 - konzolna ploča

1. Statički sistem i analiza opterećenja



$$d_p \geq \frac{l_0}{35} = \frac{400}{35} = 11.4\ cm$$

$$pretp.\ d_p = 12\ cm$$

$$g = 0.12 \times 25.0 = 3.0\ kN/m^2$$

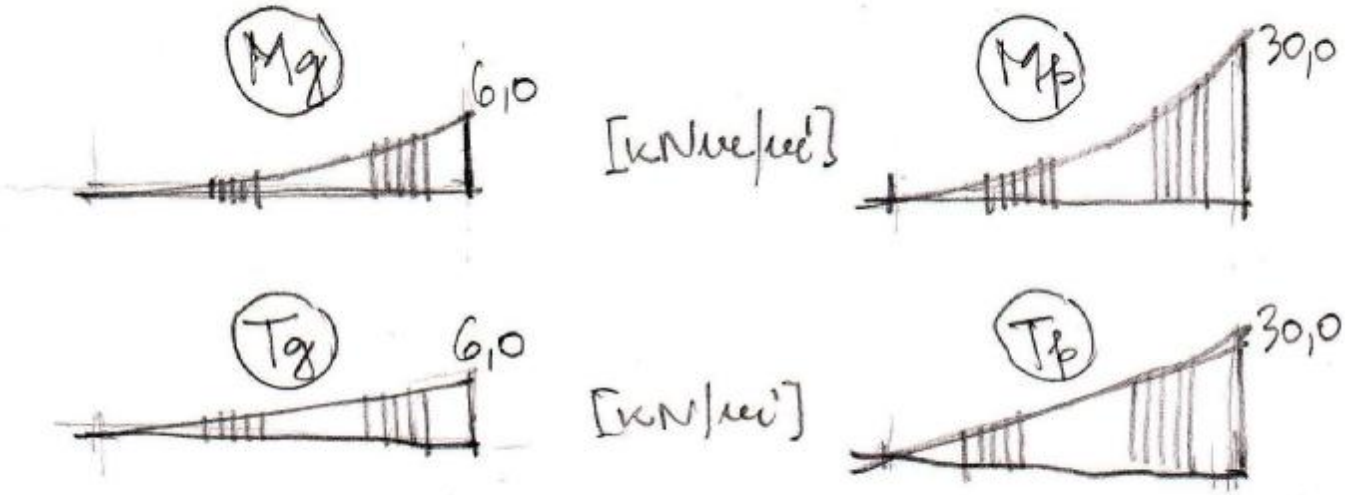
$$p = 15.0\ kN/m^2$$

2. Dijagrami presečnih sila

$$M_g = \frac{3.0 \times 2.0^2}{2} = 6.0\ kNm/m \qquad M_p = \frac{15.0 \times 2.0^2}{2} = 30.0\ kNm/m$$

$$T_g = 3.0 \times 2.0 = 6.0\ kN/m \qquad T_p = 15.0 \times 2.0 = 30.0\ kN/m$$

a. stalno opterećenje *b. povremeno opterećenje*



3. Dimenzionisanje

MB 35 → $f_b = 2.30\ kN/cm^2$

RA 400/500 → $\sigma_v = 40.0\ kN/cm^2$

$$M_u = 1.6 \times 6.0 + 1.8 \times 30.0 = 63.6\ kNm/m$$

$$pretp. \quad \varepsilon_b/\varepsilon_{a1} = 3.5/10.0\,‰ \quad \Rightarrow \quad \begin{cases} k = 2.311 \\ \overline{\mu} = 20.987\,\% \end{cases}$$

$$h_{potr.} = 2.311 \times \sqrt{\frac{63.6 \times 10^2}{100 \times 2.30}} = 12.2\ cm$$

$$pretp. \quad a_1 = 3.0\ cm \quad \Rightarrow \quad d \geq 12.2 + 3.0 = 15.2\ cm \quad \Rightarrow \quad usv.\ d = \mathbf{16\ cm}$$

Vršimo korekciju statičkih uticaja zbog povećanja sopstvene težine ploče:

$$g = 0.16 \times 25.0 = 4.0\ kN/m^2 \quad \Rightarrow \quad \begin{cases} M_g = \dfrac{4.0 \times 2.0^2}{2} = 8.0\ kNm/m \\ T_g = 4.0 \times 2.0 = 8.0\ kN/m \end{cases}$$

$$M_u = 1.6 \times 8.0 + 1.8 \times 30.0 = 66.8\ kNm/m$$

$$k = \frac{13.0}{\sqrt{\dfrac{66.8 \times 10^2}{100.0 \times 2.30}}} = 2.412 \quad \Rightarrow \quad \begin{cases} \varepsilon_b/\varepsilon_a = 3.175/10.0\,‰ \\ \overline{\mu} = 19.039\,\% \end{cases}$$

$$A_a = 19.039 \times \frac{100.0 \times 13.0}{100} \times \frac{2.30}{40.0} = 14.23\ cm^2/m$$

usvojeno **R ⌀ 14/10** ($A_a = 15.39\ cm^2/m$)

$$A_{ap} = 0.20 \times 14.23 = 2.86\ cm^2/m$$

usvojeno **R ⌀ 10/25** ($A_{ap} = 3.14\ cm^2/m$)

4. Proračun karakteristične širine prslina

$$h_{bz,ef} = min \left\{ \begin{array}{ll} 3.0 + 7.5 \times 1.4 & = 13.5\,cm \\ 16.0/2 & = 8.0\,cm \end{array} \right\} = 8.0\,cm$$

$$\mu_{z,ef} = \frac{A_{a1}}{b\,h_{bz,ef}} = \frac{15.39}{100.0 \times 8.0} = 0.019 = 1.924\,\%$$

$a_0 = 3.0 - 1.4/2 = 2.3\,cm$; $k_1 = 0.4$ (*RA* 400/500)

$e_\varnothing = 10.0\,cm$; $k_2 = 0.125$ (*savijanje*)

$$l_{ps} = 2 \times \left(2.3 + \frac{10.0}{10} \right) + 0.4 \times 0.125 \times \frac{1.4}{1.924 \times 10^{-2}} = 10.24\,cm$$

$$M = M_g + M_p = 8.0 + 30.0 = 38.0\ kNm/m$$

$$\sigma_{a1} \sim \frac{M}{0.9\,h\,A_{a1}} = \frac{38.0 \times 10^2}{0.9 \times 13.0 \times 15.39} = 21.10\ kN/cm^2$$

$$f_{bzs} = 0.7 \times 2.65 \times \left(0.6 + \frac{0.4}{\sqrt[4]{0.16}} \right) = 2.29\,MPa = 0.229\,kN/cm^2$$

$$W_{b1} = \frac{100.0 \times 16.0^2}{6} = 4266.\dot{6}\ cm^3/m$$

$$M_{crc} \sim f_{bzs}\,W_{b1} = 0.229 \times 4266.\dot{6} \times 10^{-2} = 9.75\ kNm/m < M$$

$$\left. \begin{array}{l} \beta_1 = 1.0\ (RA\ 400/500) \\ \beta_2 = 1.0\ (t=0) \end{array} \right\} \Rightarrow \xi_a = 1 - 1.0 \times 1.0 \times \left(\frac{9.75}{38.0} \right)^2 = 0.934$$

$$a_{pk} = 1.7 \times 0.934 \times \frac{21.10}{21.0 \times 10^3} \times 10.24 = 16.3 \times 10^{-3}\,cm$$

$$a_{pk} = 0.163\ mm < a_u = 0.2\ mm$$

5. Kontrola ugiba slobodnog kraja ploče

Elastično rešenje ugiba kraja konzole usled dejstva jednako raspodeljenog opterećenja q dato je izrazom:

$$v_b = \frac{q\,l^4}{8\,E_b\,J_b}$$

$$q = g + p = 4.0 + 15.0 = 19.0\,kN/m^2$$

$$MB\ 35 \quad \rightarrow \quad E_b = 33.0\,GPa = 33.0 \times 10^6\,kN/m^2$$

$$J_b = \frac{100.0 \times 16.0^3}{12} = 34\,133.\dot{3}\ cm^4/m = 34\,133.\dot{3} \times 10^{-8}\ m^4/m$$

$$v_b^{(q)} = \frac{19.0 \times 2.0^4}{8 \times 34\,133.\dot{3} \times 33.0 \times 10^{-2}} = 3.37\ mm/m$$

Deformaciju za stanje *I* (bez prslina), odnosno stanje *II* (sa prslinom) proračunavamo pomoću koeficijenata za proračun krivine elemenata pravougaonog preseka (BAB'87, tom 2 - Prilozi):

$$n = \frac{E_a}{E_b} = \frac{210.0}{33.0} = 6.36 \quad \rightarrow \quad \frac{n\,A_{a1}}{b\,h} = \frac{6.36 \times 15.39}{100.0 \times 13.0} = 0.075$$

$$\alpha_1 = \frac{a_1}{d} = \frac{3.0}{16.0} = 0.188 \sim 0.20 \quad ; \quad \alpha_2 = a_2 = A_{a2} = 0$$

Sa dijagrama (3.4.4.), odnosno (3.4.8.) u prilogu očitavamo:

$$k_a^I \sim 0.941 \quad \rightarrow \quad v_{M(t_0)}^I = 0.941 \times 3.37 = 3.18\ mm/m$$

$$k_a^{II} \sim 3.50 \quad \rightarrow \quad v_{M(t_0)}^{II} = 3.50 \times 3.37 = 11.81\ mm/m$$

Deformaciju kraja konzole u trenutku nanošenja opterećenja nalazimo kao:

$$v_M(t_0) = \left(1 - \xi_a\right) v_M^I(t_0) + \xi_a v_M^{II}(t_0) \quad ; \quad \xi_a = 1 - \beta_1 \beta_2 \frac{M_{crc}}{M} \quad \begin{cases} \geq 0.4 \\ \leq 1.0 \end{cases}$$

$$M_{crc} = f_{bzs} W_{i1} \sim f_{bzs} W_{b1} \quad ; \quad f_{bzs} = f_{bz,m}\left(0.6 + \frac{0.4}{\sqrt[4]{d}}\right) \geq f_{bz,m}$$

$$f_{bzs} = 2.65 \times \left(0.6 + \frac{0.4}{\sqrt[4]{0.16}}\right) = 3.27\ MPa = 0.327\ kN/cm^2$$

$$W_{b1} = \frac{100.0 \times 16.0^2}{6} = 4266.\dot{6}\ cm^3/m$$

$$M_{crc} \sim 0.327 \times 4266.\dot{6} = 1394.0\ kNcm/m = 13.94\ kNm/m < M = 38.0\ kNm/m$$

$$\left.\begin{array}{l} \beta_1 = 1.0\ (RA\ 400/500) \\ \beta_2 = 1.0\ (t=0) \end{array}\right\} \rightarrow \xi_a = 1 - 1.0 \times 1.0 \times \frac{13.94}{38.0} = 0.633$$

$$v_M(t_0) = (1 - 0.633) \times 3.18 + 0.633 \times 11.81 = 8.64\ mm/m$$

$$v_u = \frac{l}{150} = \frac{2000.0}{150} = 13.\dot{3}\ mm/m > v_M(t_0) = 8.64\ mm/m$$

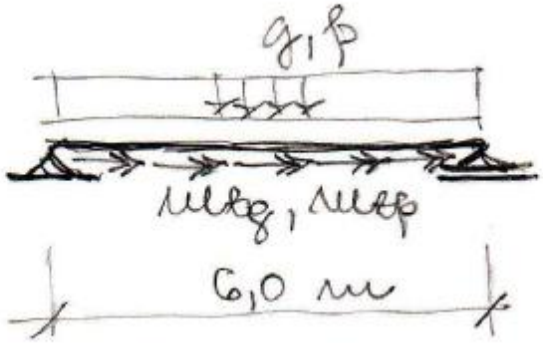
Za usvojenu debljine ploče i površinu armature, ugib kraja konzole je u dopuštenim granicama.

Generalno, u cilju smanjenja ugiba, potrebno je:

1. povećati debljinu ploče (povećanje momenta inercije betonskog preseka i smanjenje elastičnog ugiba), i/ili
2. povećati količinu zategnute armature u preseku (smanjenje napona u armaturi, čime se smanjuje krivina, odnosno povećava krutost nosača, naročito u isprskalom stanju), i/ili
3. postaviti armaturu u pritisnutu zonu preseka, čime se znatno smanjuje uticaj tečenja betona

POS 2 - kontinualna greda

1. Statički sistem i analiza opterećenja



s.t. POS 2: $0.6 \times 0.8 \times 25.0 = 12.0\ kN/m$

od POS 1: $R_{g1} = 8.0\ kN/m$

ukupno: $g = \mathbf{20.0\ kN/m}$

$m_{T,g} = M_{g1} = \mathbf{8.0\ kNm/m}$

od POS 1: $R_{p1} = p = \mathbf{30.0\ kN/m}$

$m_{T,p} = M_{p1} = \mathbf{30.0\ kNm/m}$

2. Dijagrami presečnih sila

$M_g = 20.0 \times 6.0^2 / 8 = 90.0\ kNm$

$T_g = 20.0 \times 6.0 / 2 = 60.0\ kN$

$M_{T,g} = 8.0 \times 6.0 / 2 = 24.0\ kNm$

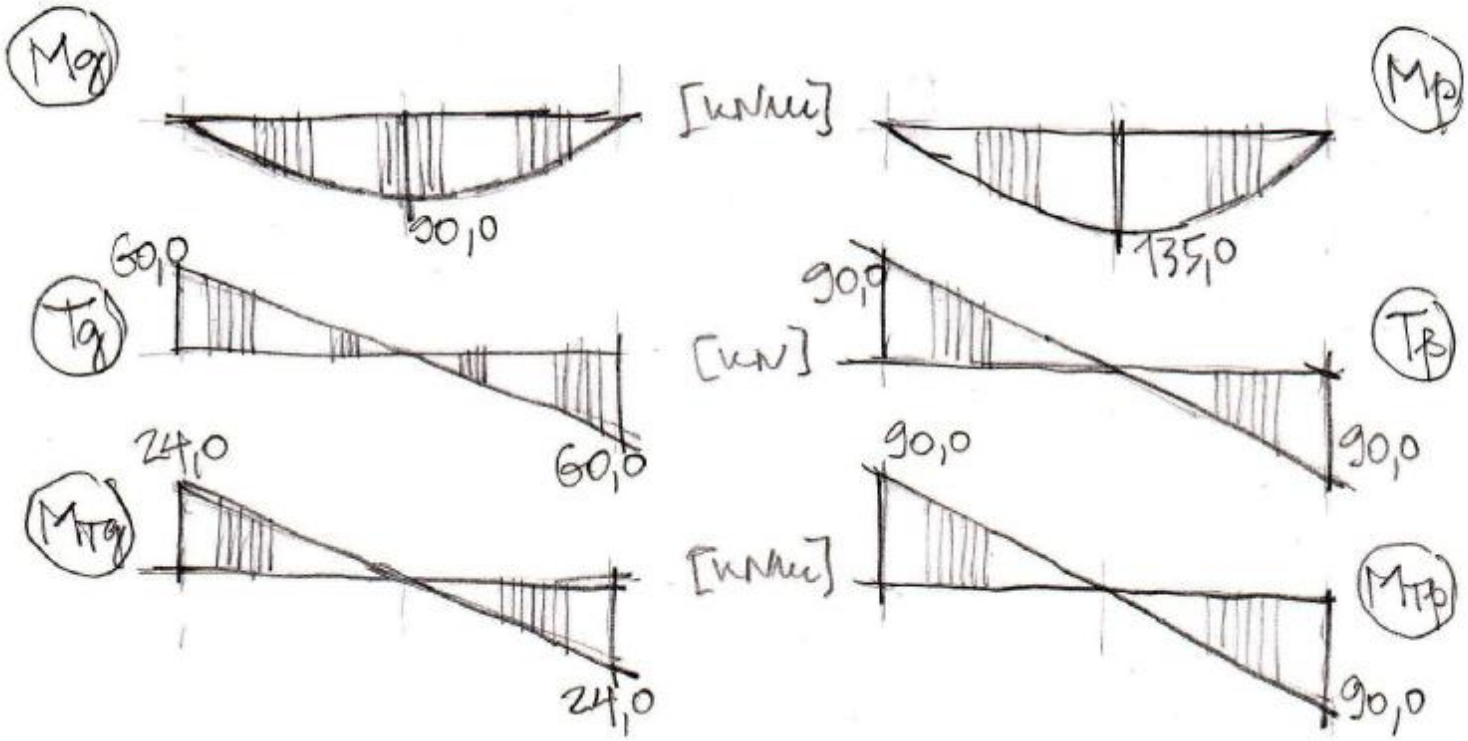
$M_p = 30.0 \times 6.0^2 / 8 = 135.0\ kNm$

$T_p = 30.0 \times 6.0 / 2 = 90.0\ kN$

$M_{T,p} = 30.0 \times 6.0 / 2 = 90.0\ kNm$

a. stalno opterećenje

b. povremeno opterećenje



3. Dimenzionisanje

$$M_u = 1.6 \times 90.0 + 1.8 \times 135.0 = 387.0\ kNm$$

$$B \le min. \left\{ \begin{array}{ll} 60.0 + 8 \times 16.0 & = 168.0\ cm \\ 60.0 + \dfrac{0.25}{3} \times 600.0 & = 110.0\ cm \\ l_{POS\,1} & = 200.0\ cm \end{array} \right\} = 110.0\ cm$$

Pretpostavljamo da se neutralna linija nalazi u ploči, pa presek dimenzionišemo kao pravougaoni, širine $B = 110\ cm$:

$$pretp.\ \ a_1 = 5.0\ cm \quad \Rightarrow \quad h = 80.0 - 5.0 = 75.0\ cm$$

$$k = \frac{75.0}{\sqrt{\dfrac{387.0 \times 10^2}{110.0 \times 2.30}}} = 6.046 \quad \rightarrow \quad \left\{ \begin{array}{rl} \varepsilon_b / \varepsilon_a & = 0.85/10.0\,‰ \\ \overline{\mu} & = 2.858\,\% \\ s & = 0.078 \end{array} \right.$$

$$x = s\,h = 0.078 \times 75.0 = 5.85\ cm < d_p = 16.0\ cm$$

Pretpostavka o položaju neutralne linije je bila tačna, pa se potrebna površina armature određuje kao:

$$A_a = 2.858 \times \frac{110.0 \times 75.0}{100} \times \frac{2.30}{40.0} = 13.56\ cm^2$$

$$A_{a,min} = 0.20 \times \frac{60.0 \times 80.0}{100} = 9.60\ cm^2 < A_{a,potr.} = 13.56\ cm^2$$

usvojeno **5 R ⌀ 19** $(A_a = 14.18\ cm^2)$

3.1. Kontrola glavnih napona zatezanja

$$M_{Tu} = 1.6 \times 24.0 + 1.8 \times 90.0 = 200.4\ kNm$$

$$T_u = 1.6 \times 60.0 + 1.8 \times 90.0 = 258.0\ kN$$

$$\left.\begin{aligned} b_0 &\sim 60.0 - 8.0 = 52.0\,cm \\ d_0 &\sim 80.0 - 8.0 = 72.0\,cm \end{aligned}\right\} \Rightarrow \left\{\begin{aligned} A_{b0} &= 52.0 \times 72.0 = 3744.0\,cm^2 \\ O_{b0} &= 2 \times (52.0 + 72.0) = 248.0\,cm \end{aligned}\right.$$

$$\delta_0 \le \frac{52.0}{8} = 6.5\,cm \quad ; \quad usv.\ \ \delta_0 = 6.5\,cm$$

$$\left.\begin{aligned} \tau_n^{(T)} &= \frac{258.0}{60.0 \times 0.9 \times 75.0} = 0.064\ kN/cm^2 \\ \tau_n^{(M_T)} &= \frac{200.4 \times 10^2}{2 \times 3744.0 \times 6.5} = 0.412\ kN/cm^2 \end{aligned}\right\} \Rightarrow \tau_n = 0.476\ kN/cm^2$$

$$\tau_n = 0.476\ kN/cm^2 \quad \left\{\begin{aligned} &> 3\,\tau_r = 0.36\ kN/cm^2 \\ &< 5\,\tau_r = 0.60\ kN/cm^2 \end{aligned}\right\} \Rightarrow T_{bu} = M_{Tbu} = 0$$

$$usvojeno \quad \left\{\begin{aligned} m &= 4 \\ \alpha &= 90^\circ \\ \theta &= 40^\circ \end{aligned}\right\} \Rightarrow a_{u,T}^{(1)} = \frac{0.064 \times 60.0}{4 \times 40.0 \times (0 + 1 \times 1.192)}\, e_u = 0.020\, e_u$$

$$a_{u,M_T}^{(1)} = \left(\frac{200.4 \times 10^2}{2 \times 3744.0 \times 40.0} \times 0.839\right) e_u = 0.056\, e_u$$

$$a_{u,sp.}^{(1)} = (0.020 + 0.056)\, e_{u,sp.} = 0.076\ e_{u,sp.}$$

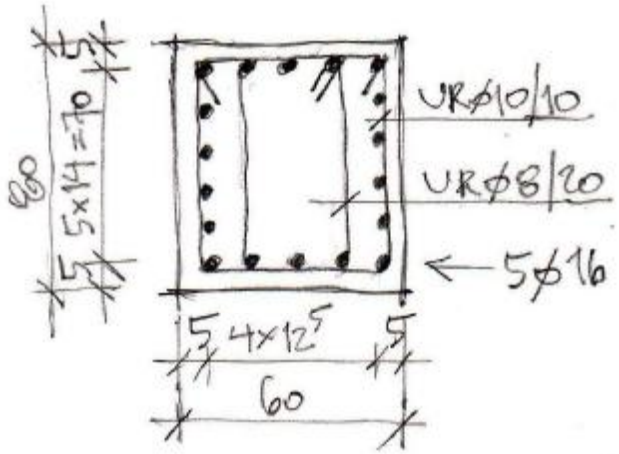
$$a_{u,un.}^{(1)} = 0.020\ e_{u,un.}$$

$$pretp.\ \ UR\varnothing 10 \Rightarrow e_{u,sp.} \le \frac{0.785}{0.076} = 10.31\ cm \Rightarrow usv.\ UR\varnothing 10/10$$

$$pretp.\ \ UR\varnothing 8 \Rightarrow e_{u,un.} \le \frac{0.503}{0.020} = 25.36\ cm \Rightarrow usv.\ UR\varnothing 8/20$$

$$\Delta A_a = \frac{258.0}{2 \times 40.0} \times (1.192 - 0) = 3.84\ cm^2$$

$$\Sigma A_a = \frac{200.4 \times 10^2 \times 248.0}{2 \times 3744.0 \times 40.0} \times 1.192 = 19.78\ cm^2 \rightarrow \mathbf{18\ R \varnothing 12}\ (20.36\ cm^2)$$

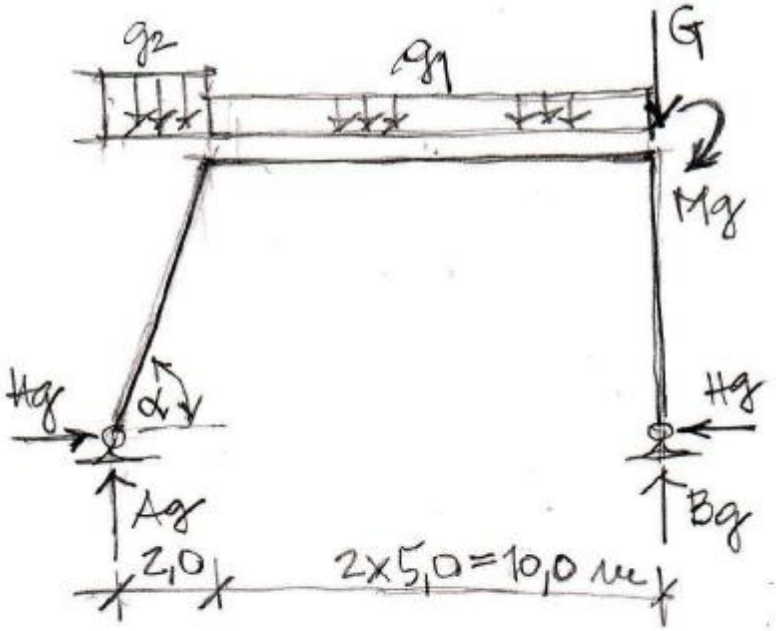


za T:		$3.84\ cm^2$
za M_T:	$5\ R \varnothing 12$	$(5.65\ cm^2)$
ukupno:		$9.49\ cm^2$
usvojeno :	$\mathbf{5\ R \varnothing 16}$	$(10.05\ cm^2)$

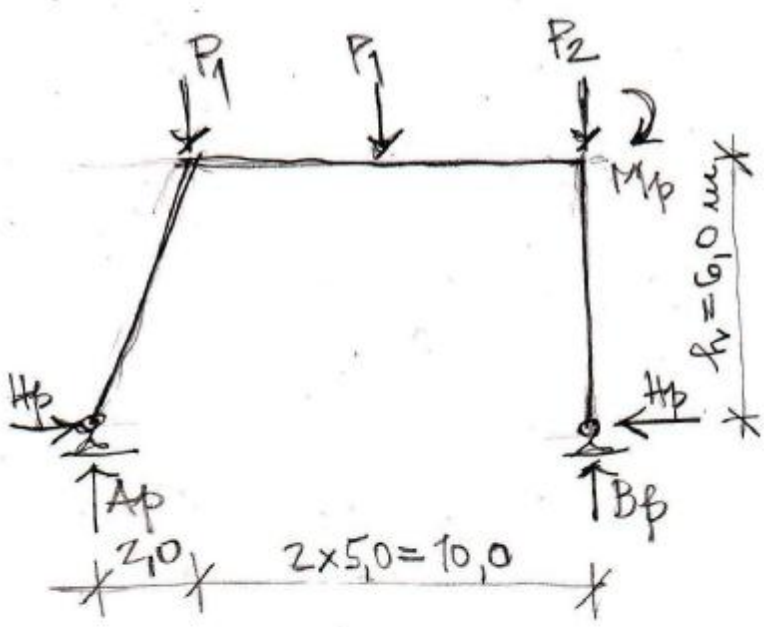
POS 3, POS S1, POS S2

1. Statički sistem i analiza opterećenja

a. stalno opterećenje



b. povremeno opterećenje



$$tg\,\alpha = \frac{6.0}{2.0} = 3.0 \rightarrow \begin{cases} \alpha = 71.57^\circ \\ \cos\alpha = 0.316 \end{cases}$$

$$g_1 = 0.4 \times 1.0 \times 25.0 = 10.0\ kN/m$$

$$g_2 = \frac{0.4 \times 0.6 \times 25.0}{0.316} = 19.0\ kN/m$$

$$G = R_g^{(POS2)} = 60.0\ kN$$

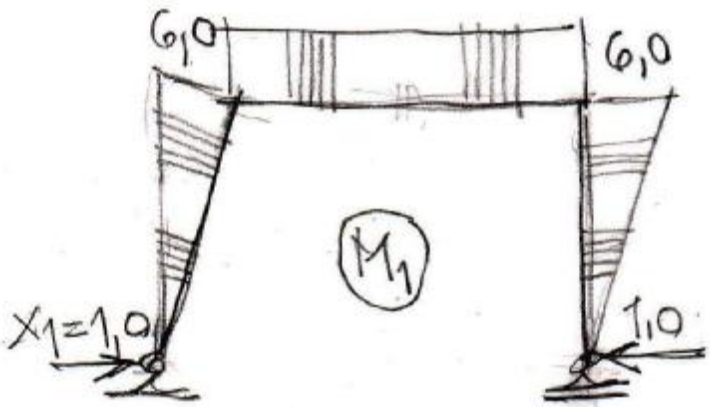
$$M_g = M_{T,g}^{(POS2)} = 24.0\ kNm$$

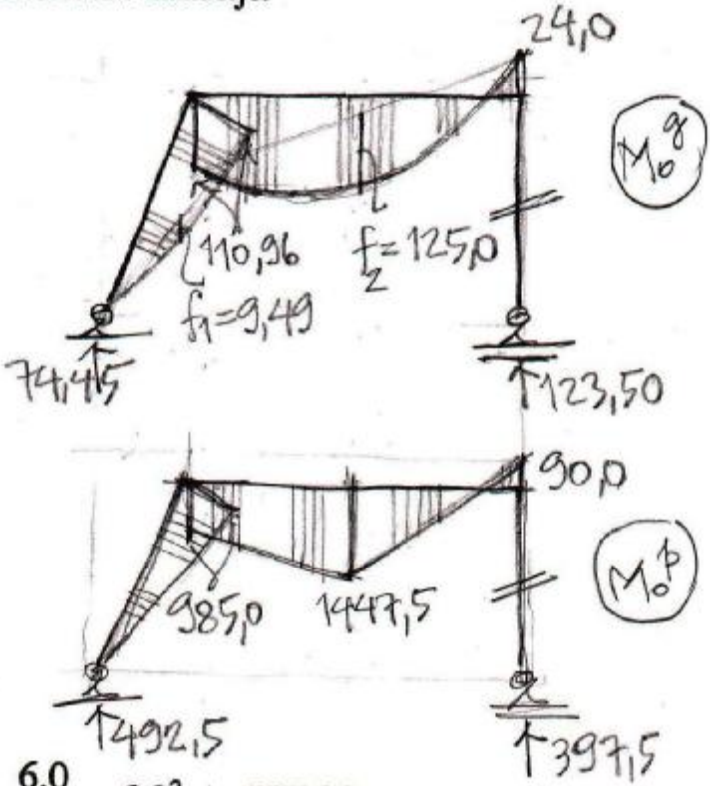
$$P_1 = P = 400.0\ kN$$

$$P_2 = R_p^{(POS2)} = 90.0\ kN$$

$$M_p = M_{T,p}^{(POS2)} = 90.0\ kNm$$

2. Proračun statičkih uticaja





$$E_b J_b \delta_{11} = \frac{6.33}{3} \times 6.0^2 + 10.0 \times 6.0^2 + \frac{6.0}{3} \times 6.0^2 = 507.90$$

$$-E_b J_b \delta_{10}^g = \frac{6.33}{3} \times 6.0 \times (110.96 + 9.49) +$$

$$+ 10.0 \times 6.0 \times \left(\frac{110.96 - 24.0}{2} + \frac{2}{3} \times 125.0 \right) = 9132.18$$

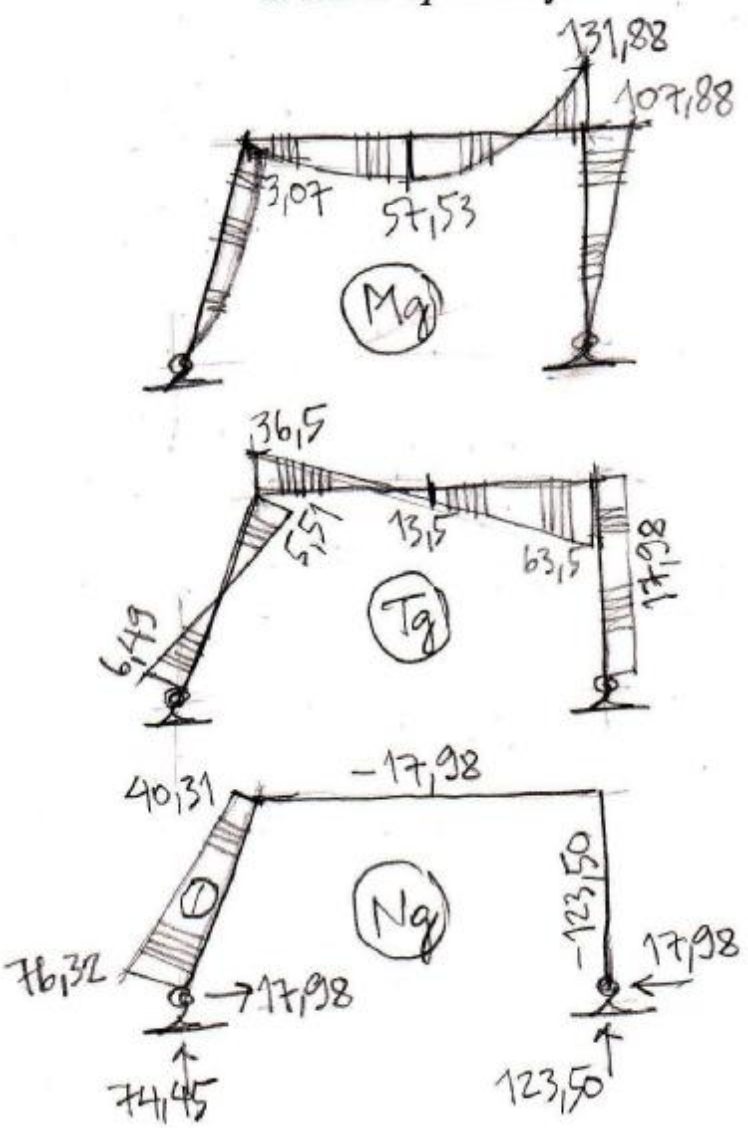
$$-E_b J_b \delta_{10}^p = 5.0 \times 6.0 \times \left(\frac{985.0 + 1447.5}{2} + \frac{1447.5 - 90.0}{2} \right) +$$

$$+ \frac{6.33}{3} \times 985.0 \times 6.0 = 69309.4$$

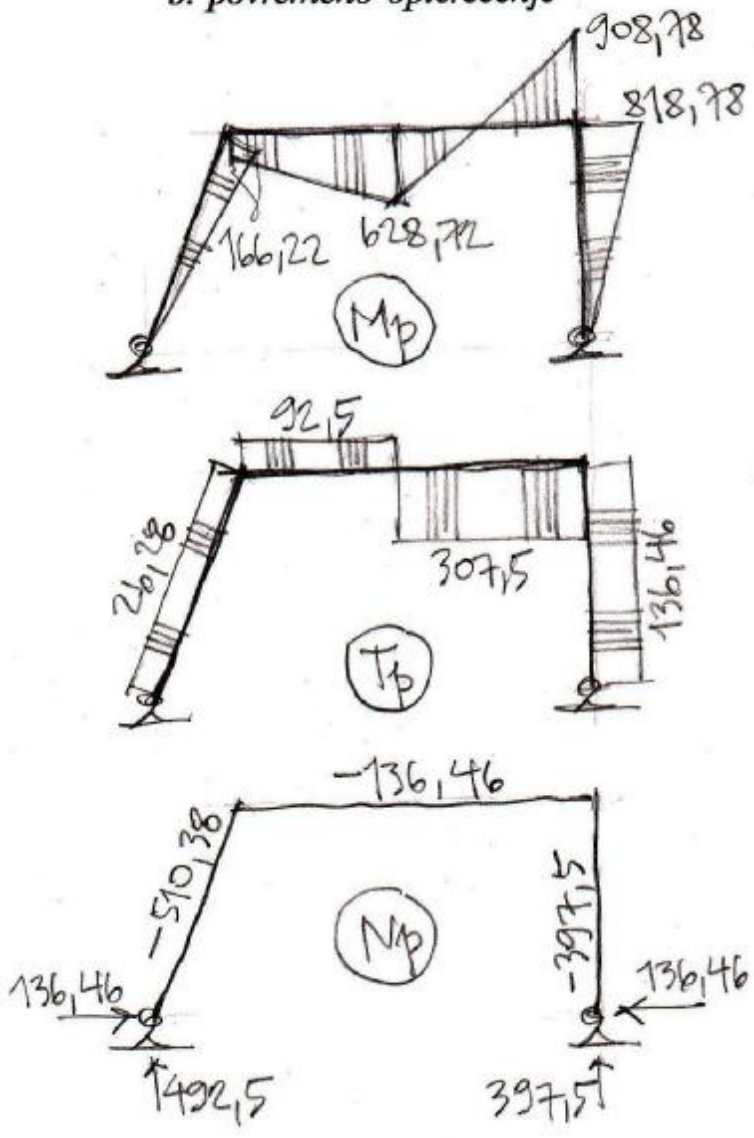
$$X_1^{(g)} = \frac{9132.18}{507.90} = 17.98\ kN \quad ; \quad X_1^{(p)} = \frac{69309.4}{507.90} = 136.46\ kN$$

3. Dijagrami presečnih sila

a. stalno opterećenje



b. povremeno opterećenje



3. Dimenzionisanje **POS 3**

a. presek 1-1

$$M_u = 1.6 \times 131.88 + 1.8 \times 908.78 = 1846.8\ kNm$$

$$N_u = 1.6 \times 17.98 + 1.8 \times 136.46 = 274.4\ kN$$

pretp. $a_1 = 8.0\ cm \quad \Rightarrow \quad h = 100.0 - 8.0 = 92.0\ cm$

$$M_{au} = 1846.8 + 274.4 \times \left(\frac{1.00}{2} - 0.08 \right) = 1962.1 \ kNm$$

$$k = \frac{92.0}{\sqrt{\frac{1962.1 \times 10^2}{40.0 \times 2.30}}} = 1.992 \quad \Rightarrow \quad \begin{cases} \varepsilon_b / \varepsilon_a = 3.5/6.0 \text{‰} \\ \overline{\mu} = 29.824 \% \end{cases}$$

$$A_a = 29.824 \times \frac{40.0 \times 92.0}{100} \times \frac{2.30}{40.0} - \frac{274.4}{40.0} = 56.25 \ cm^2$$

usvojeno **12 R ⌀ 25** $(A_a = 58.91 \ cm^2)$

b. presek 2-2

$$M_u = 1.6 \times 57.53 + 1.8 \times 628.72 = 1223.7 \ kNm$$

$$N_u = 274.4 \ kN$$

pretp. $a_1 = 6.0 \ cm \quad \Rightarrow \quad h = 100.0 - 6.0 = 94.0 \ cm$

$$M_{au} = 1223.7 + 274.4 \times \left(\frac{1.00}{2} - 0.06 \right) = 1344.5 \ kNm$$

$$k = \frac{94.0}{\sqrt{\frac{1344.5 \times 10^2}{40.0 \times 2.30}}} = 2.459 \quad \Rightarrow \quad \begin{cases} \varepsilon_b / \varepsilon_a = 3.05/10.0 \text{‰} \\ \overline{\mu} = 18.263 \% \end{cases}$$

$$A_a = 18.263 \times \frac{40.0 \times 94.0}{100} \times \frac{2.30}{40.0} - \frac{274.4}{40.0} = 32.63 \ cm^2$$

usvojeno **7 R ⌀ 25** $(A_a = 34.36 \ cm^2)$

3.1. Kontrola glavnih napona zatezanja

$$T_u^{(1)} = 1.6 \times 63.5 + 1.8 \times 307.5 = 655.1\ kN$$

$$T_u^{(2d)} = 1.6 \times 13.5 + 1.8 \times 307.5 = 575.1\ kN$$

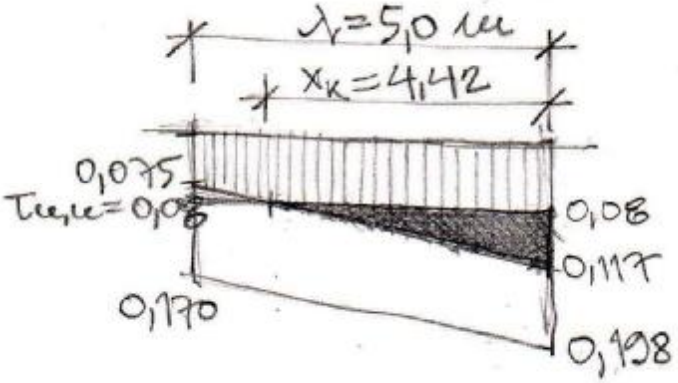
$$T_u^{(2l)} = 1.8 \times 92.5 - 1.0 \times 13.5 = 153.0\ kN$$

$$T_u^{(3)} = 1.6 \times 36.5 + 1.8 \times 92.5 = 224.9\ kN$$

$$\tau_n^{(1)} = \frac{655.1}{40.0 \times 0.9 \times 92.0} = 0.198\ kN/cm^2$$

$$\tau_n^{(2d)} = \frac{575.1}{40.0 \times 0.9 \times 94.0} = 0.170\ kN/cm^2$$

$$\tau_n^{(3)} = \frac{224.9}{40.0 \times 0.9 \times 95.0} = 0.066\ kN/cm^2 < \tau_r = 1.2\ kN/cm^2$$



$$\tau_{Ru}^{(1)} = \frac{3}{2} \times (0.198 - 0.12) = 0.117\ kN/cm^2$$

$$\tau_{Ru}^{(2d)} = \frac{3}{2} \times (0.170 - 0.12) = 0.075\ kN/cm^2$$

Osiguranje od glavnih napona zatezanja se vrši vertikalnim uzengijama, određenim iz zadovoljenja minimalnog procenta armiranja $\mu_{uz} = 0.2\%$, i koso povijenim profilima:

$$\textit{usvojeno} \quad \left\{ \begin{array}{lll} \theta = 45^\circ & ; & m = 4 \\ \alpha = 90^\circ & ; & UR \varnothing 8 \quad (a_u^{(1)} = 0.503\ cm^2) \end{array} \right\}$$

$$\mu_{uz,min} = 0.2\ \% \quad \Rightarrow \quad e_u \le \frac{4 \times 0.503}{40.0 \times 0.2 \times 10^{-2}} = 25.1\ kN/cm^2$$

usvojeno	$UR \varnothing 8/25$	$(m = 4)$

$$\tau_{u,u} = \frac{4 \times 0.503}{40.0 \times 25.0} \times 40.0 \times (0 + 1.0 \times 1.0) = 0.080\ kN/cm^2$$

$$H_{vu,k} = \frac{0.117 - 0.080}{2} \times 442.0 \times 40.0 = 320.5\ kN$$

$$\alpha_k = 45° \quad \Rightarrow \quad A_{ak} = \frac{320.5}{40.0 \times (0.707 + 0.707 \times 1.0)} = 5.66\ cm^2$$

usvojeno **2 R ⌀ 25** $(A_a = 9.82\ cm^2)$

4. Dimenzionisanje **POS S1**

$$M_u = 1.6 \times 3.1 + 1.8 \times 166.2 = 304.1\ kNm$$

$$N_u = 1.6 \times 40.3 + 1.8 \times 510.4 = 983.2\ kN$$

$$pretp.\ a_1 = 5.0\ cm \quad \Rightarrow \quad h = 60.0 - 5.0 = 55.0\ cm$$

$$M_{au} = 304.1 + 983.2 \times \left(\frac{0.60}{2} - 0.05 \right) = 549.9\ kNm$$

$$k = \frac{55.0}{\sqrt{\frac{549.9 \times 10^2}{40.0 \times 2.30}}} = 2.250 \quad \Rightarrow \quad \begin{cases} \varepsilon_b / \varepsilon_a = 3.5/9.20\ ‰ \\ \overline{\mu} = 22.309\ \% \end{cases}$$

$$A_a = 22.309 \times \frac{40.0 \times 55.0}{100} \times \frac{2.30}{40.0} - \frac{983.2}{40.0} = 3.64\ cm^2$$

$$A_{a,min} = 0.20 \times \frac{40.0 \times 60.0}{100} = 4.80\ cm^2$$

usvojeno **± 2 R ⌀ 19** $(A_{a1} = A_{a2} = 5.67\ cm^2)$

Za ovako određenu armaturu i datu graničnu računsku silu, sa dijagrama interakcije možemo odrediti moment loma preseka:

$$\left.\begin{aligned} \frac{a_1}{d} &= \frac{4.5}{60.0} && \approx 0.075 \\ \bar{\mu}_1 &= \bar{\mu}_2 = \frac{5.67}{40.0 \times 60.0} \times \frac{40.0}{2.3} && = 0.041 \\ n_u &= \frac{983.2}{40.0 \times 60.0 \times 2.30} && = 0.178 \end{aligned}\right\} \rightarrow \left\{\begin{aligned} \varepsilon_a &\approx 10.0\,‰ \\ m_u &\approx 0.106 \end{aligned}\right.$$

$$M_R = 0.106 \times 40.0 \times 60.0^2 \times 2.30 \times 10^{-2} = 351.1\ kNm > M_u = 304.1\ kNm$$

5. Dimenzionisanje **POS S2**

$$M_u = 1.6 \times 107.9 + 1.8 \times 818.8 = 1646.4\ kNm$$

$$N_u = 1.6 \times 123.5 + 1.8 \times 397.5 = 913.1\ kN$$

$$pretp.\ \ a_1 = 8.0\ cm \quad \Rightarrow \quad h = 80.0 - 8.0 = 72.0\ cm$$

$$M_{au} = 1646.4 + 913.1 \times \left(\frac{0.80}{2} - 0.08\right) = 1938.6\ kNm$$

$$k = \frac{72.0}{\sqrt{\dfrac{1938.6 \times 10^2}{40.0 \times 2.30}}} = 1.568 \quad \Rightarrow \quad \varepsilon_a < 3\,‰ \quad \Rightarrow \quad dvojno\ armiranje$$

$$usvojeno \quad \varepsilon_b / \varepsilon_{a1} = 3.5 / 5.0\,‰ \quad \rightarrow \quad \left\{\begin{aligned} k &= 1.903 \\ \bar{\mu} &= 33.333\,\% \end{aligned}\right.$$

$$M_{abu} = \left(\frac{72.0}{1.903}\right)^2 \times 0.40 \times 2.30 = 1317.0\ kNm$$

$$\Delta M_{au} = 1938.6 - 1317.0 = 621.6\ kNm$$

$$A_{a1} = 33.333 \times \frac{40.0 \times 72.0}{100} \times \frac{2.30}{40.0} + \frac{621.6 \times 10^2}{40.0 \times (72.0 - 5.0)} - \frac{913.1}{40.0} = 55.57\ cm^2$$

$$A_{a2} = \frac{621.6 \times 10^2}{40.0 \times (72.0 - 5.0)} = 23.20\ cm^2$$

usvojeno

12 R ⌀ 25 $(A_{a1} = 58.91\ cm^2)$

5 R ⌀ 25 $(A_{a2} = 24.54\ cm^2)$

$$T_u = 1.6 \times 17.98 + 1.8 \times 136.46 = 274.4\ kN$$

$$\tau_n = \frac{274.4}{40.0 \times (0.9 \times 72.0)} = 0.106\ kN/cm^2 < \tau_r = 0.12\ kN/cm^2$$

Nije potrebno osiguranje armaturom od dejstva transverzalnih sila.