**POS 1a, POS 1b**

$$L_1 = 3.0 \text{ m}$$

$$L_2 = 2.0 \text{ m}$$

$$d_p = 20 \text{ cm}$$

$$\Delta g = 2.0 \text{ kN/m}^2$$

$$p = 5.0 \text{ kN/m}^2$$

POS S

$$\lambda = 6.0 \text{ m}$$

$$b = 25 \text{ cm}$$

POS 1a

sopstvena teжина ploče

$$d_p \times \gamma_b = 0.20 \times 25.0 = 5.0 \text{ kN/m}^2$$

dodatno stalno opterećenje:

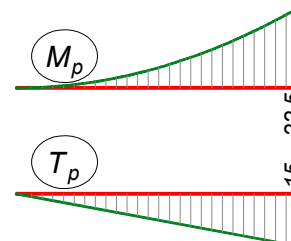
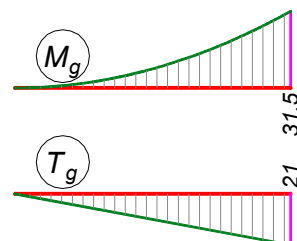
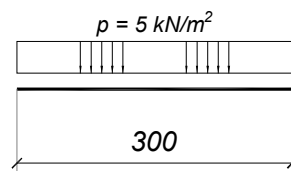
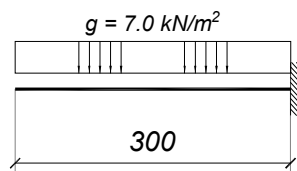
$$\Delta g = 2.0 \text{ kN/m}^2$$

ukupno stalno opterećenje:

$$g = 7.0 \text{ kN/m}^2$$

povremeno opterećenje:

$$p = 5.0 \text{ kN/m}^2$$



POS 1a

$$M_u = 1.6 \times 31.5 + 1.8 \times 22.5 = 90.9 \text{ kNm/m}$$

$$\text{pretp. } a_1 = 3 \text{ cm} \Rightarrow h = 20 - 3 = 17 \text{ cm}$$

$$\text{MB 30} \Rightarrow f_B = 20.5 \text{ MPa}$$

$$k = \frac{17}{\sqrt{\frac{90.9}{2.05}}} = 2.553 \Rightarrow \frac{\varepsilon_b}{\varepsilon_a} = 2.825 / 10\text{‰}$$

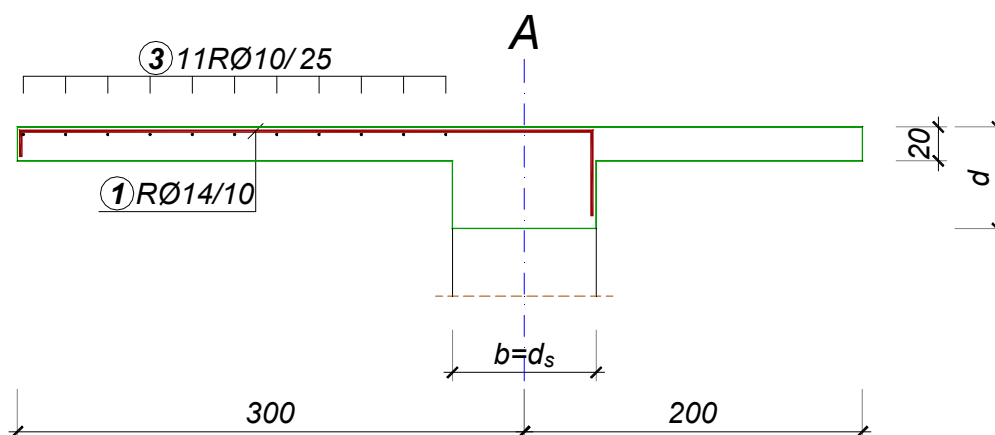
$$\mu = 16.826\%$$

$$A_{a,\text{potr.}} = 16.826 \times 17 \times \frac{2.05}{40} = 14.66 \frac{\text{cm}^2}{\text{m}}$$

usvojeno: **RØ14/10** (15.40 cm²/m)

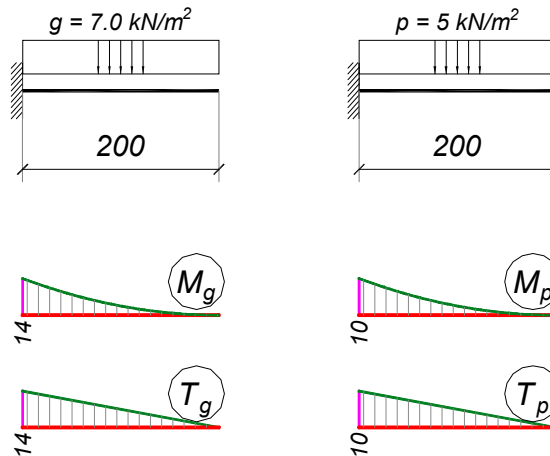
$$A_{ap,\text{potr.}} = 0.20 \times 14.66 = 2.93 \text{ cm}^2/\text{m}$$

usvojeno: **RØ10/25** (3.14 cm²/m)

POS 1a – usvojena armatura

POS 1b

sopstvena teжина ploče	$d_p \times \gamma_b = 0.20 \times 25.0$	= 5.0 kN/m ²
dodatno stalno opterećenje:	Δg	= 2.0 kN/m ²
ukupno stalno opterećenje:	g	= 7.0 kN/m ²
povremeno opterećenje:	$p =$	= 5.0 kN/m ²

**POS 1b**

$$M_u = 1.6 \times 14 + 1.8 \times 10 = 40.4 \text{ kNm/m}$$

$$\text{pretp. } a_1 = 3 \text{ cm} \Rightarrow h = 20 - 3 = 17 \text{ cm}$$

$$k = \frac{17}{\sqrt{\frac{40.4}{2.05}}} = 3.829 \Rightarrow \frac{\varepsilon_b}{\mu} / \varepsilon_a = 1.475 / 10\text{‰}$$

$$\mu = 7.151\%$$

$$A_{a,\text{potr.}} = 7.151 \times 17 \times \frac{2.05}{40} = 6.23 \frac{\text{cm}^2}{\text{m}}$$

usvojeno: **RØ14/20** (7.70 cm²/m)

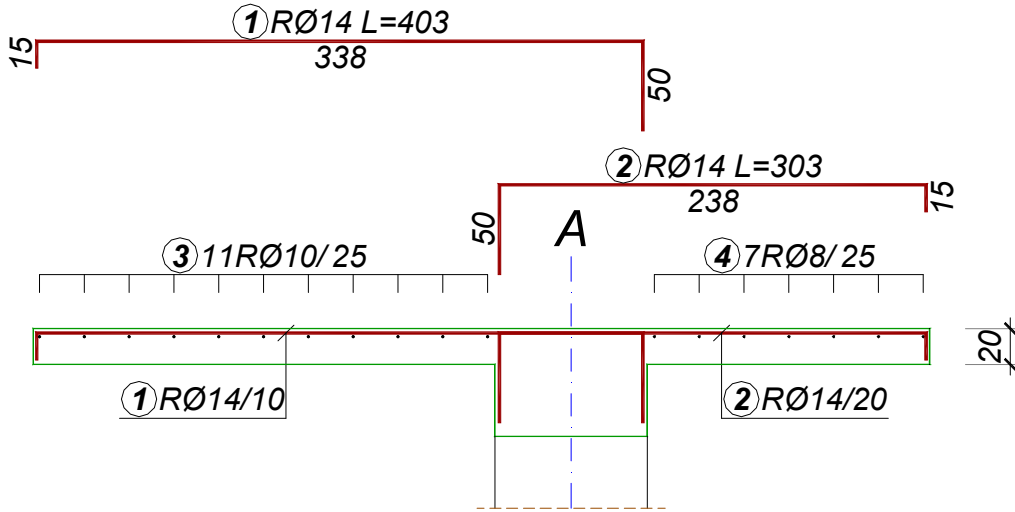
$$A_{ap,\text{potr.}} = 0.20 \times 6.23 = 1.25 \text{ cm}^2/\text{m}$$

$$A_{ap,\text{min.}} = 0.085 \times 20 = 1.70 \text{ cm}^2/\text{m} > A_{ap,\text{potr.}}$$

usvojeno: **RØ8/25** (2.01 cm²/m)

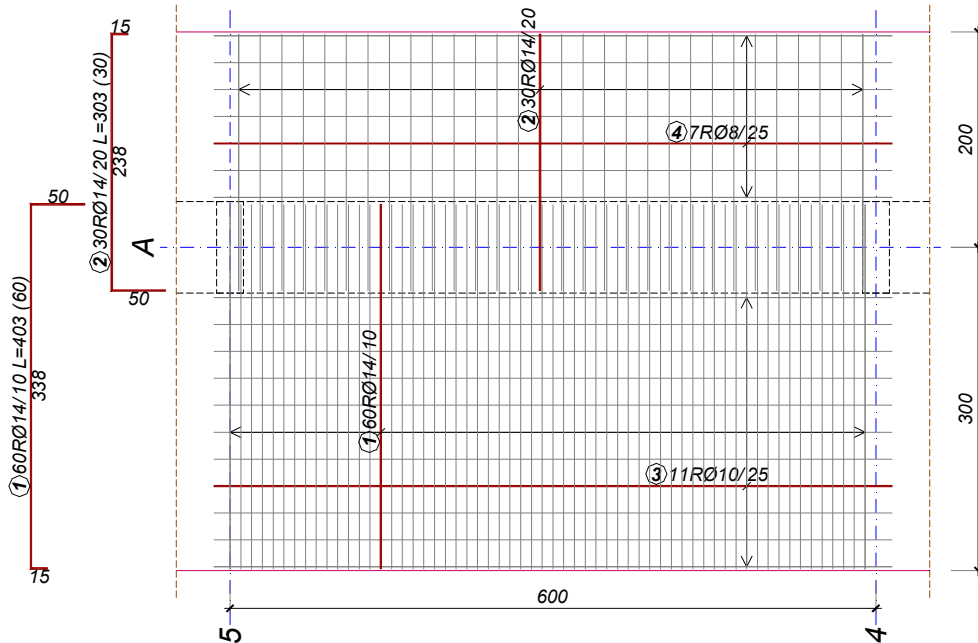
POS 1a, 1b – usvojena armatura (varijanta 2)

7



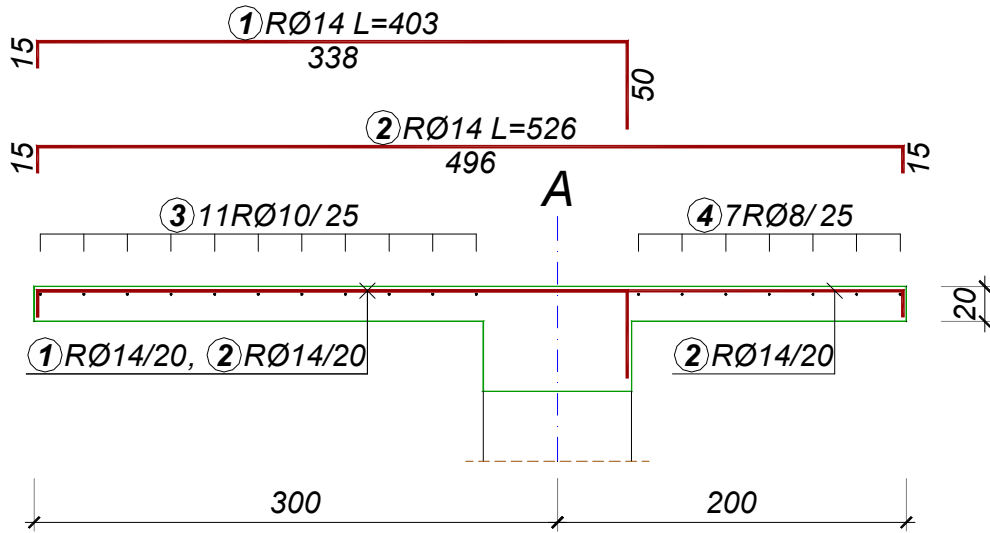
POS 1a, 1b – armatura u osnovi (varijanta 2)

8



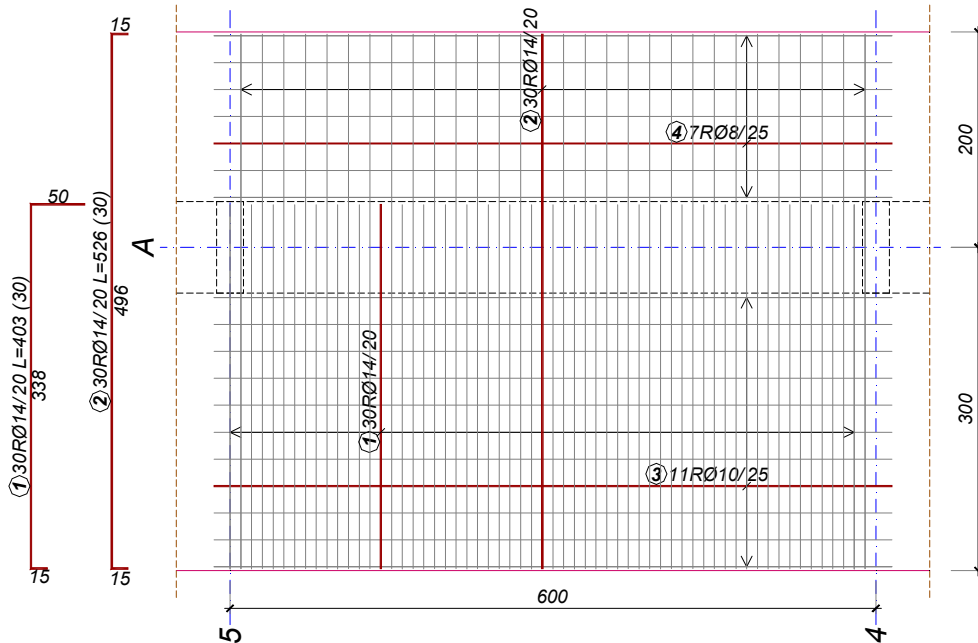
POS 1a, 1b – usvojena armatura (varijanta 1)

9



POS 1a, 1b – armatura u osnovi (varijanta 1)

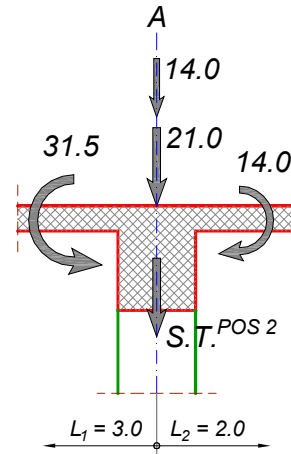
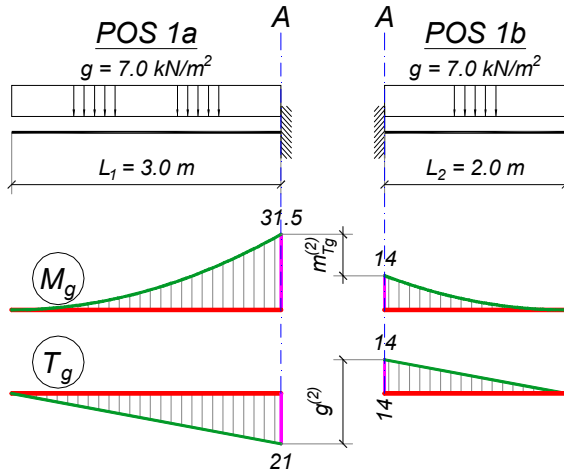
10



POS 2stalno opterećenje:

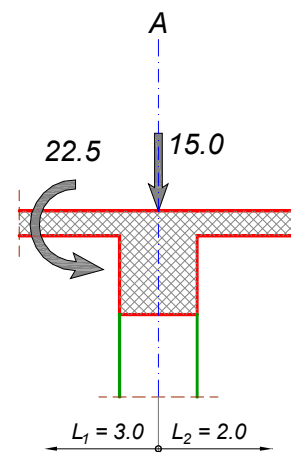
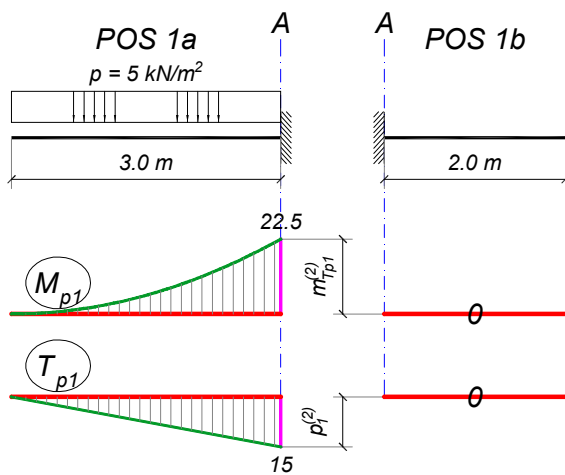
$$m_{Tg} = 31.5 - 14 = 17.5 \text{ kNm/m}$$

$$g = 21 - (-14) = 35.0 \text{ kN/m}$$

**POS 2**povremeno opterećenje na POS 1a:

$$m_{Tp1} = 22.5 - 0 = 22.5 \text{ kNm/m}$$

$$p_1 = 15 - 0 = 15.0 \text{ kN/m}$$

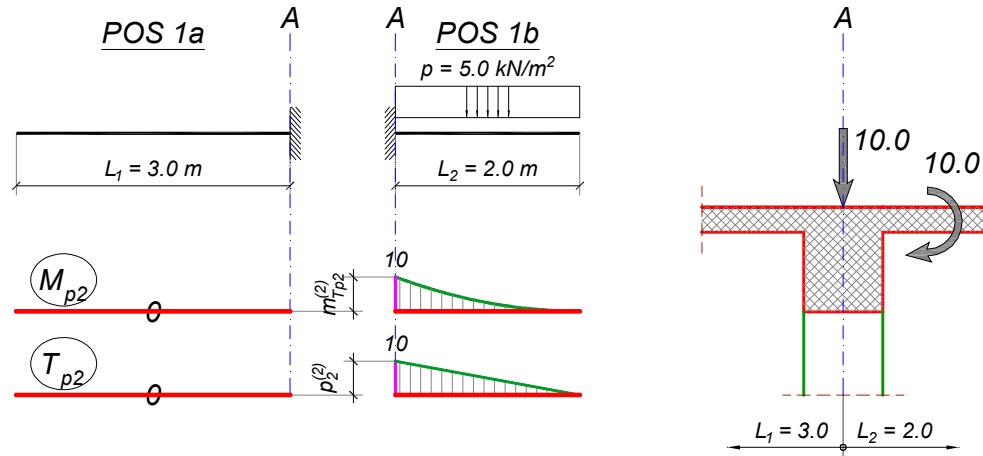


POS 2

povremeno opterećenje na POS 1b:

$$m_{Tp2} = 0 - 10 = -10.0 \text{ kNm/m}$$

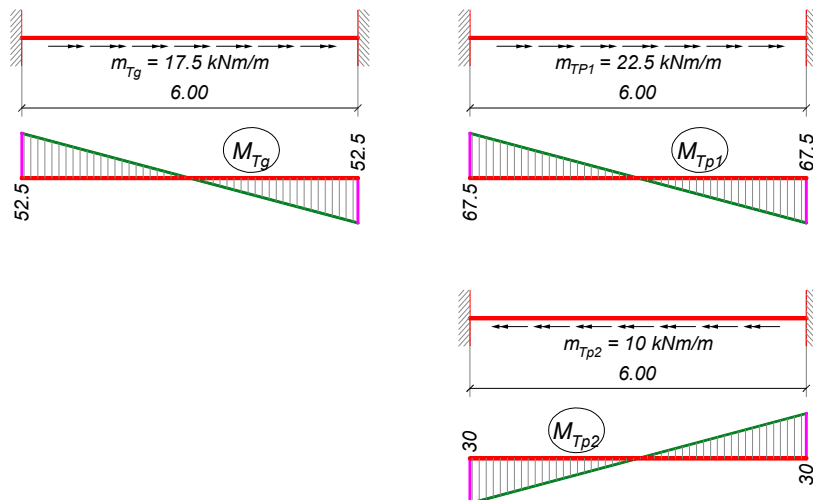
$$p_2 = 0 - (-10) = 10.0 \text{ kN/m}$$

**POS 2 - dimenzionisanje prema M_T**

$$M_{Tg} = 17.5 \times 6.0 / 2 = 52.5 \text{ kNm}$$

$$M_{Tp1} = 22.5 \times 6.0 / 2 = 67.5 \text{ kNm}$$

$$M_{Tp2} = -10 \times 6.0 / 2 = -30 \text{ kNm}$$



POS 2 - dimenzionisanje prema M_T

$$M_{Tu} = 1.6 \times 52.5 + 1.8 \times 67.5 = 205.5 \text{ kNm}$$

$$MB 30 \Rightarrow \tau_r = 1.1 \text{ MPa}$$

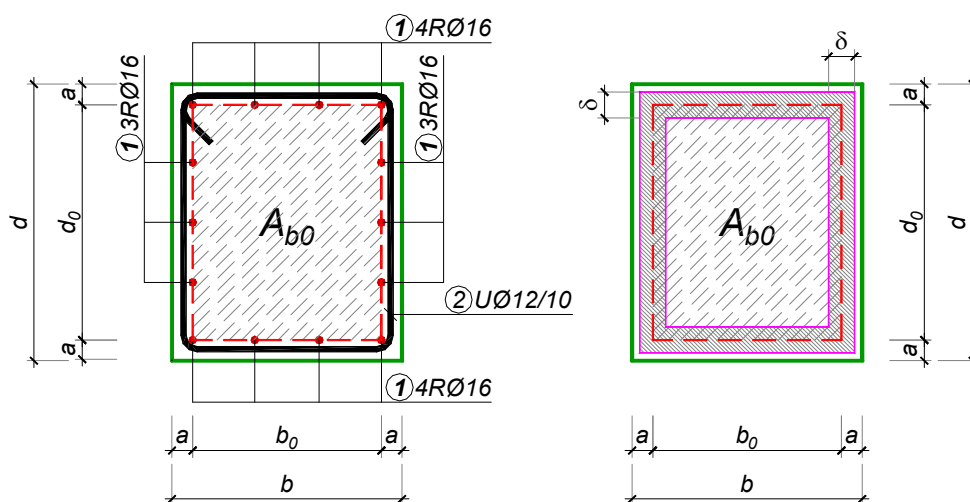
$$\tau_n^{M_T} = \frac{M_{Tu}}{2 \times A_{b0} \times \delta_0} = 0.44 \frac{\text{kN}}{\text{cm}^2} = 4\tau_r$$

$$A_{b0} = b_0 \times d_0 = (b - 2a) \times (d - 2a)$$

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

pretp. $a = 4.5 \text{ cm}$, $b \leq d$:

$$A_{b0} = b_0 \times d_0 = (b - 9) \times (d - 9)$$



$$\delta_o = \frac{b-9}{8} \Rightarrow \frac{205.5 \times 10^2}{2 \times (b-9) \times (d-9) \times \frac{b-9}{8}} = 0.44$$

$$(b-9)^2 \times (d-9) = \frac{8 \times 205.5 \times 10^2}{2 \times 0.44} = 186818 \text{ cm}^3$$

<i>b</i>	<i>d</i>	<i>d usv.</i>
50	120.1	125
55	97.3	100
60	80.8	85
65	68.6	70

usvojeno: $b / d = 85 / 60 \text{ cm}$

2.4 ANALIZA OPTEREĆENJA

stalno opterećenje

- sopstvena težina $0.85 \times 0.60 \times 25 = 12.8 \text{ kN/m}$

- od POS 1a, 1b $= 35.0 \text{ kN/m}$

ukupno, stalno opterećenje: $g = 47.8 \text{ kN/m}$

raspodeljeni moment torzije $m_{Tg} = 17.5 \text{ kNm/m}$

povremeno opterećenje sa POS 1a

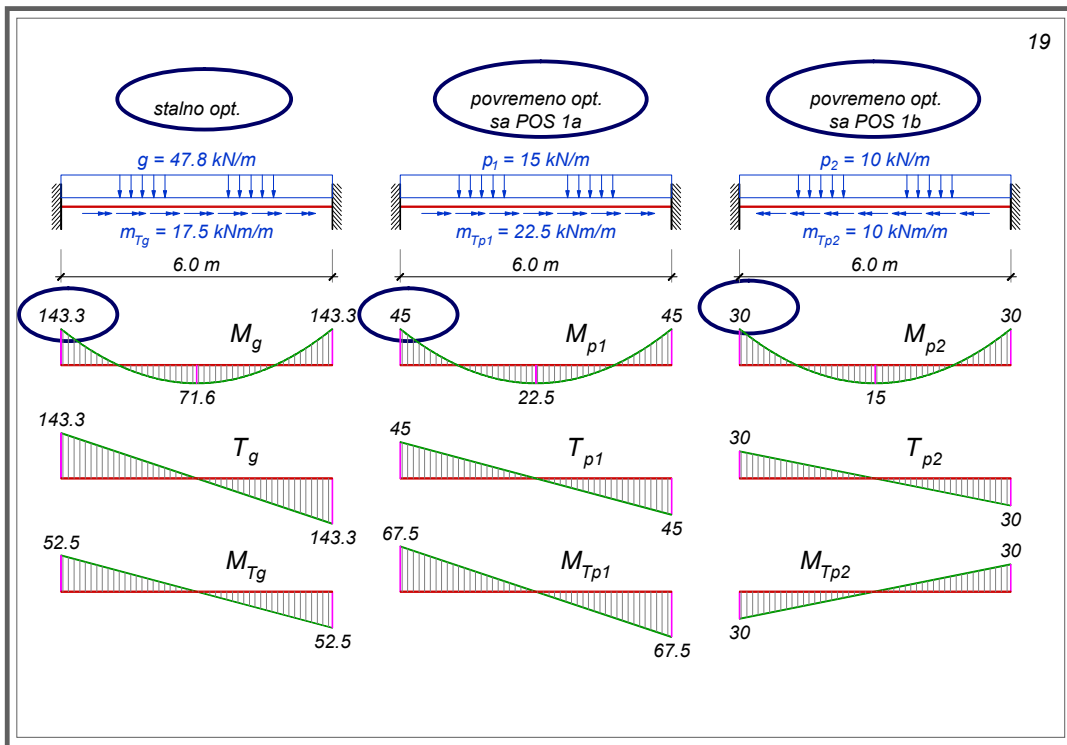
raspodeljeno opterećenje $p_1 = 15.0 \text{ kN/m}$

raspodeljeni moment torzije $m_{Tp1} = 22.5 \text{ kNm/m}$

povremeno opterećenje sa POS 1b

raspodeljeno opterećenje $p_2 = 10.0 \text{ kN/m}$

raspodeljeni moment torzije $m_{Tp2} = -10.0 \text{ kNm/m}$



2.6 DIMENZIONISANJE POS 2 PREMA MOMENTIMA SAVIJANJA

Maksimalni momenti savijanja se javljaju kada je poprečno opterećenje najveće, odnosno kada povremeno opterećenje deluje istovremeno na POS 1a i POS 1b.

2.6.1 Presek nad osloncem

$$M_u = 1.6 \times 143.3 + 1.8 \times (45 + 30) = 364.2 \text{ kNm}$$

$$\text{pretp. } a_1 = 5 \text{ cm} \Rightarrow h = 60 - 5 = 55 \text{ cm}$$

$$k = \frac{55}{\sqrt{\frac{364.2 \times 10^2}{85 \times 2.05}}} = 3.804 \Rightarrow \varepsilon_b/\varepsilon_a = 1.488/10\text{‰} ; \bar{\mu} = 7.248\%$$

$$A_{a,\text{potr.}} = \underline{\underline{7.248 \times \frac{85 \times 55}{100} \times \frac{2.05}{40} = 17.37 \text{ cm}^2}}$$

2.6.2 Presek u polju

$$M_u = 1.6 \times 71.6 + 1.8 \times (22.5 + 15) = 182.1 \text{ kNm}$$

Pritisnuta je gonja ivica preseka, pa je oblik pritisnute zone ili **T** ili pravougaoni, širine B :

$$B = \min. \left\{ \begin{array}{l} b + 20 \times d_p = 85 + 20 \times 20 = 485 \text{ cm} \\ b + 0.25 \times l_0 = 85 + 0.25 \times 0.6 \times 600 = 175 \text{ cm} \end{array} \right\} = 175 \text{ cm}$$

Pretpostavlja se da je neutralna linija u ploči. Sledi:

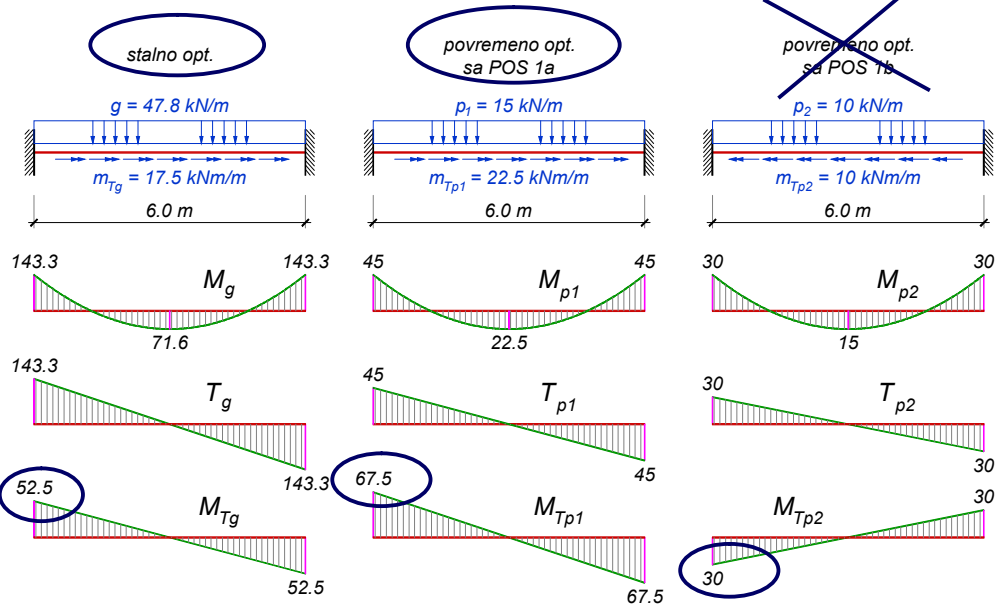
$$\text{pretp. } a_1 = 5 \text{ cm} \Rightarrow h = 60 - 5 = 55 \text{ cm}$$

$$k = \frac{55}{\sqrt{\frac{182.1 \times 10^2}{175 \times 2.05}}} = 7.720 \Rightarrow \varepsilon_b/\varepsilon_a = 0.639/10\text{‰} ; \bar{\mu} = 1.713\% ; s = 0.060$$

$$x = 0.060 \times 55 = 3.3 \text{ cm} < d_p = 20 \text{ cm}$$

$$A_{a,\text{potr.}} = 1.713 \times \frac{175 \times 55}{100} \times \frac{2.05}{40} = 8.45 \text{ cm}^2$$

$$A_{a,\text{min.}} = \underline{\underline{\mu_{\text{min.}} \times b \times d = \frac{0.2}{100} \times 85 \times 60 = 10.2 \text{ cm}^2 > A_{a,\text{potr.}}}}$$



2.7.1 Povremeno opterećenje samo na POS 1a

$$M_{Tu} = 1.6 \times 52.5 + 1.8 \times 67.5 = 205.5 \text{ kNm} = M_{Tu, \max}$$

$$T_u = 1.6 \times 143.3 + 1.8 \times 45 = 310.2 \text{ kN}$$

$$A_{b0} = (85 - 2 \times 4.5) \times (60 - 2 \times 4.5) = 76 \times 51 = 3876 \text{ cm}^2$$

$$O_{b0} = 2 \times (76 + 51) = 254 \text{ cm}$$

$$\delta_o = \frac{51}{8} = 6.38 \text{ cm} \Rightarrow \tau_{n(M_r)} = \frac{205.5 \times 10^2}{2 \times 3876 \times 6.38} = 0.416 \frac{\text{kN}}{\text{cm}^2}$$

$$z \approx 0.9 \times 55 = 49.5 \text{ cm} \Rightarrow \tau_{n(T)} = \frac{310.2}{85 \times 49.5} = 0.074 \frac{\text{kN}}{\text{cm}^2}$$

$$\tau_n = 0.416 + 0.074 = 0.49 \text{ kN/cm}^2 < 5 \tau_r = 0.55 \text{ kN/cm}^2$$

$$\lambda = \frac{L}{2} \times \left(1 - \frac{\tau_r}{\tau_n}\right) = \frac{600}{2} \times \left(1 - \frac{0.11}{0.49}\right) = 233 \text{ cm}$$

Osiguranje se vrši vertikalnim uzengijama i horizontalnom armaturom. Potrebna površina uzengija se sračunava iz odgovarajućih redukovanih uticaja (M_{TRu} , odnosno τ_{Ru}), posebno za uticaj momenta torzije, odnosno transverzalne sile¹.

$$\tau_n > 3 \tau_r = 0.33 \text{ kN/cm}^2 \Rightarrow T_{bu} = M_{Tbu} = 0$$

2.7.1.1 Potrebna armatura za prihvatanje transverzalne sile

Kako je procenat armiranja uzengijama potrebnim za osiguranje uticaja od transverzalne sile minimalno 0.2%, najpre će biti sračunat napon koji mogu prihvatiti ove uzengije:

$$\text{usvojeno: } \alpha = 90^\circ ; \theta = 45^\circ$$

$$\tau_{uu, \min}^T = \frac{m \times a_{u,T}^{(1)}}{b \times e_u} \times \sigma_v \times (\cos \alpha + \sin \alpha \times \cot \theta) = \mu_{uz} \times \sigma_v = 0.2 \times 10^{-2} \times 40 = 0.08 \frac{\text{kN}}{\text{cm}^2}$$

$$\tau_{uu, \min}^T > \tau_{Ru(T)} = \tau_{n(T)} = 0.074 \frac{\text{kN}}{\text{cm}^2}$$

Radi lakšeg poređenja rezultata usvojeno je $m=2$:

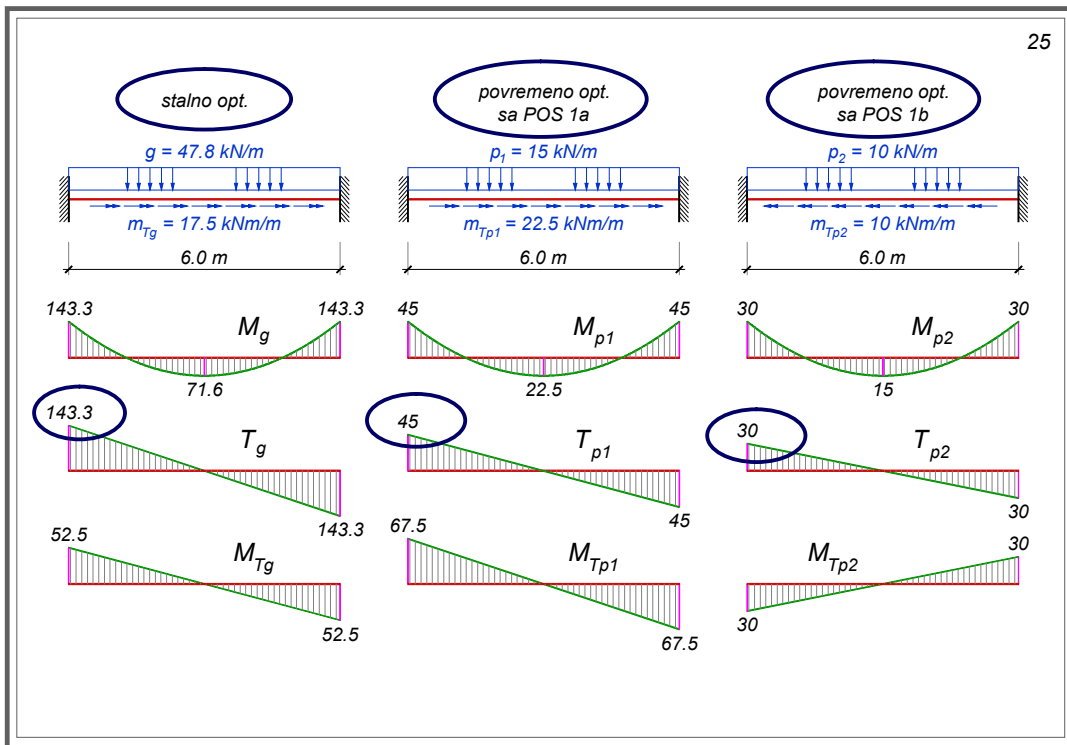
$$a_{u,T}^{(1)} = \frac{b \times \tau_{Ru}^T}{m \times \sigma_v} \times \frac{1}{(\cos \alpha + \sin \alpha \times \cot \theta)} \times e_u = \frac{85 \times 0.080}{2 \times 40} \times \frac{1}{(0 + 1 \times 1)} \times e_u = \underline{\underline{0.085 \times e_u}}$$

$$\Delta A_a = 0 \text{ ("špic" momenta)}$$

2.7.1.2 Potrebna armatura za prihvatanje torzije

$$a_{u, M_r}^{(1)} = \frac{M_{TRu}}{2 \times A_{b0} \times \sigma_v} \times \tan \theta \times e_u = \frac{205.5 \times 10^2}{2 \times 3876 \times 40} \times 1.0 \times e_u = \underline{\underline{0.066 \times e_u}}$$

$$\sum A_a = \frac{M_{Tu}}{2 \times A_{b0} \times \sigma_v} \times \cot \theta \times O_{b0} = \frac{205.5 \times 10^2}{2 \times 3876 \times 40} \times 1.0 \times 254 = 16.83 \text{ cm}^2$$



2.7.2 Povremeno opterećenje istovremeno na POS 1a i POS 1b

$$T_u = 1.6 \times 143.3 + 1.8 \times (45 + 30) = 364.2 \text{ kN} = \max. T_u$$

$$M_{Tu} = 1.6 \times 52.5 + 1.8 \times (67.5 - 30) = 151.5 \text{ kNm}$$

$$\tau_{n(T)} = \frac{364.2}{85 \times 49.5} = 0.087 \frac{\text{kN}}{\text{cm}^2}$$

$$\tau_{n(M_T)} = \frac{151.5 \times 10^2}{2 \times 3876 \times 6.38} = 0.307 \frac{\text{kN}}{\text{cm}^2}$$

$$\tau_n = 0.307 + 0.087 = 0.394 \text{ kN/cm}^2 < 5\tau_r = 0.55 \text{ kN/cm}^2$$

$$\tau_n > 3\tau_r = 0.33 \text{ kN/cm}^2 \Rightarrow T_{bu} = M_{Tbu} = 0$$

2.7.2.1 Potrebna armatura za prihvatanje transverzalne sile

$$a_{u,T}^{(t)} = \frac{85 \times 0.087}{2 \times 40} \times \frac{1}{(0+1 \times 1)} \times e_u = \underline{\underline{0.092 \times e_u}}$$

$$\Delta A_a = 0 \text{ ("špic" momenta)}$$

2.7.2.2 Potrebna armatura za prihvatanje torzije

$$a_{u,M_T}^{(t)} = \frac{151.5 \times 10^2}{2 \times 3876 \times 40} \times 1.0 \times e_u = \underline{\underline{0.049 \times e_u}}$$

$$\sum A_a = \frac{151.5 \times 10^2}{2 \times 3876 \times 40} \times 1.0 \times 254 = 12.42 < 16.83 \text{ cm}^2$$

2.8.1 Usvajanje poprečne armature

Upoređivanjem napred sračunatih potrebnih površina uzengija, može se zaključiti da je merodavan slučaj kada povremeno opterećenje deluje samo na POS 1a:

$$a_u^{(1)} = a_{u,T}^{(1)} + a_{u,M_T}^{(1)} = (0.085 + 0.066) \times e_u = 0.151 \times e_u \quad (\text{opterećenje } g + p_1)$$

$$a_u^{(1)} = a_{u,T}^{(1)} + a_{u,M_T}^{(1)} = (0.092 + 0.049) \times e_u = 0.141 \times e_u \quad (\text{opterećenje } g + p_1 + p_2)$$

Usvajajući ČETVOROSEČNE uzengije za prihvatanje transversalne sile, sledi:

2.8.1.1 Spoljašnja uzengija

$$a_u^{(1)} = \frac{a_{u,T}^{(1)}}{2} + a_{u,M_T}^{(1)} = \left(\frac{0.085}{2} + 0.066 \right) \times e_u = 0.109 \times e_u$$

$$U\emptyset 12 \quad (a_u^{(1)} = 1.13 \text{ cm}^2) \Rightarrow e_u = 1.13 / 0.109 = 10.4 \text{ cm}$$

usvojeno: **U \emptyset 12/10**

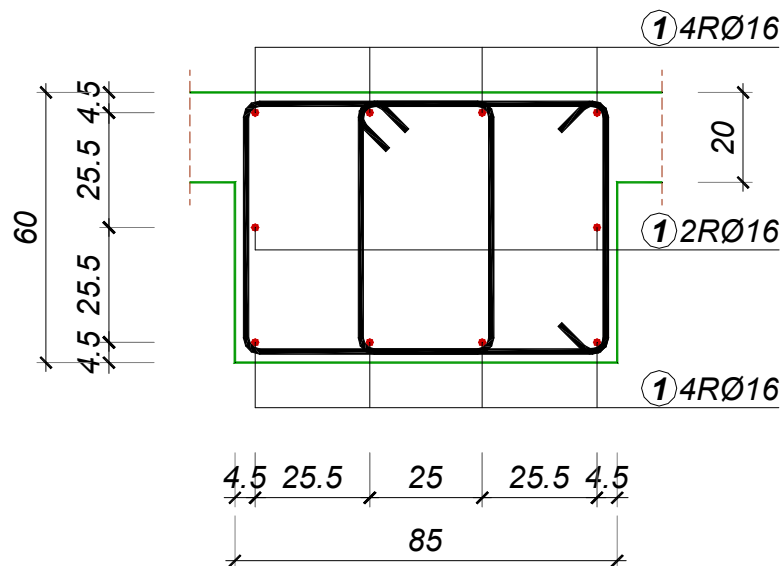
2.8.1.2 Unutrašnja uzengija

$$a_u^{(1)} = \frac{a_{u,T}^{(1)}}{2} = \frac{0.085}{2} \times e_u = 0.043 \times e_u$$

$$U\emptyset 12 \quad (a_u^{(1)} = 1.13 \text{ cm}^2) \Rightarrow e_u = 1.13 / 0.043 = 26.6 \text{ cm}$$

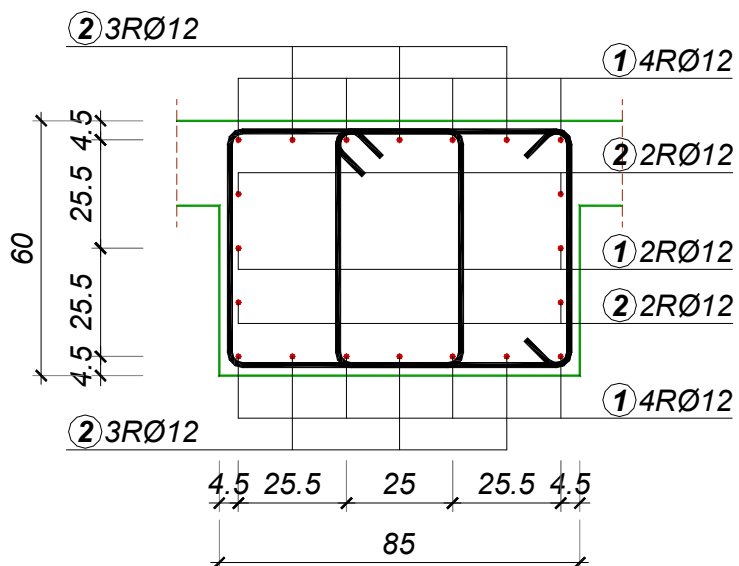
usvojeno: **U \emptyset 12/20**

Potencijalni raspored podužne armature (var. 1)



Potencijalni raspored podužne armature (var. 2)

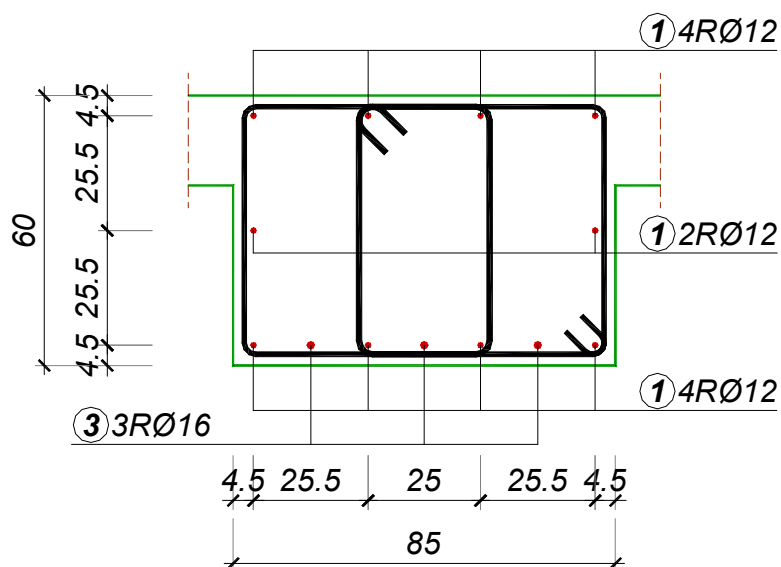
29



usvajanje armature u polju

30

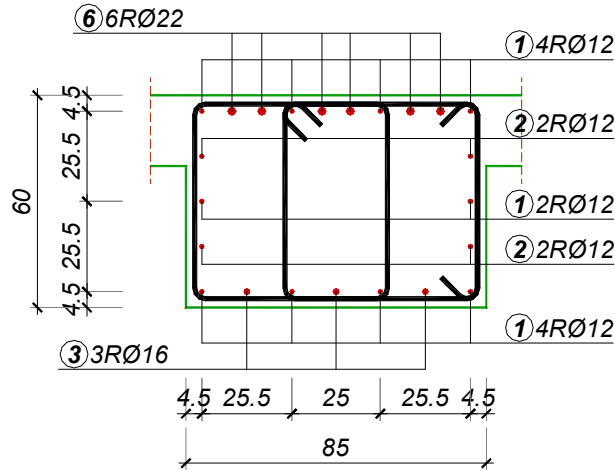
$$A_{a, \text{potr.}} - 4RØ12 = 10.20 - 4.52 = 5.68 \text{ cm}^2 \Rightarrow \text{usvojeno } 3RØ16 (6.03 \text{ cm}^2)$$



usvajanje armature nad osloncem

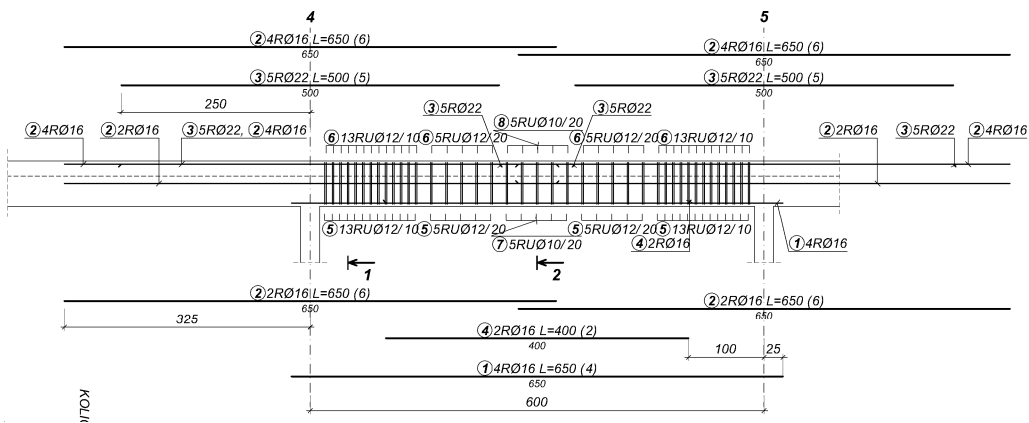
31

- potrebna armatura (torzija): usvojeno: $7R\emptyset 12 = 7.92 \text{ cm}^2$
- potrebna armatura (savijanje): $A_{a, \text{potr.}} = 17.37 \text{ cm}^2$
- ukupno, savijanje i torzija: $17.37 + 7.92 = 25.29 \text{ cm}^2$
- nedostajuće (dodatne šipke): $25.29 - 4R\emptyset 12 = 25.29 - 4.52 = 20.76 \text{ cm}^2$
usvojeno **6R $\emptyset 22$** (22.81 cm^2)



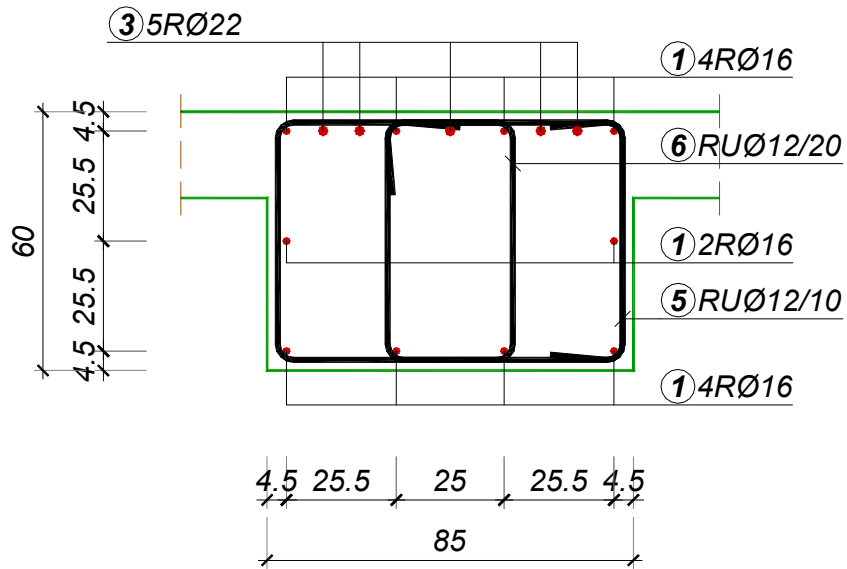
Podužni presek POS 2

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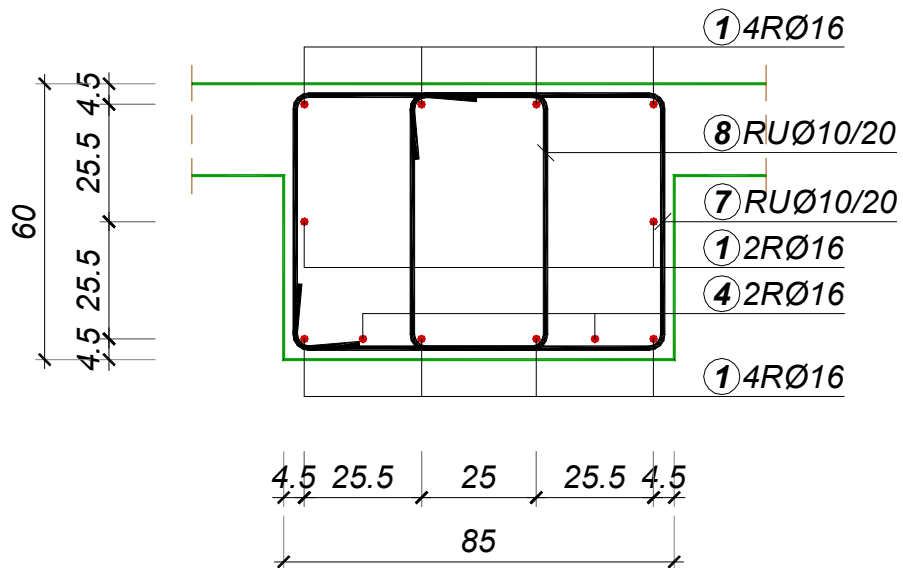
Usvojeni preseći POS 2 – presek nad osloncem

33



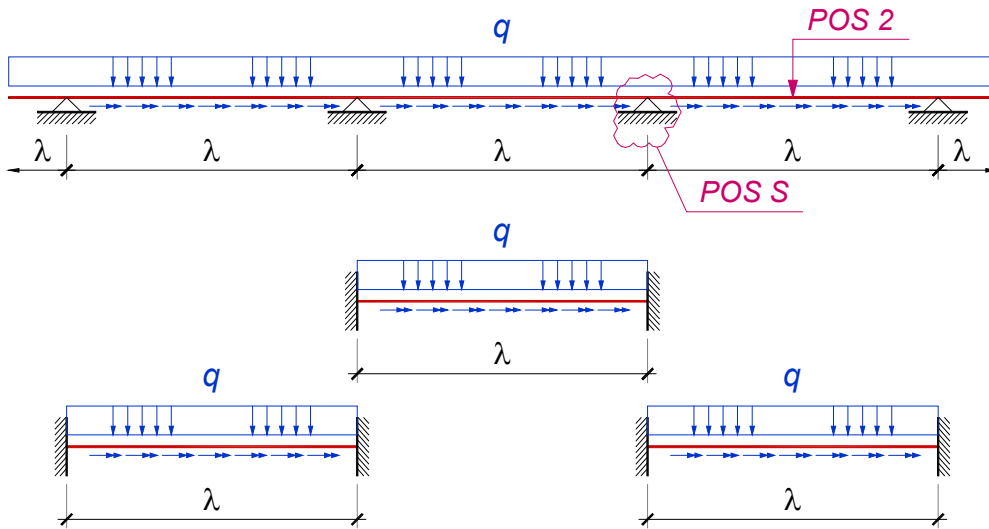
Usvojeni preseći POS 2 – presek u polju

34

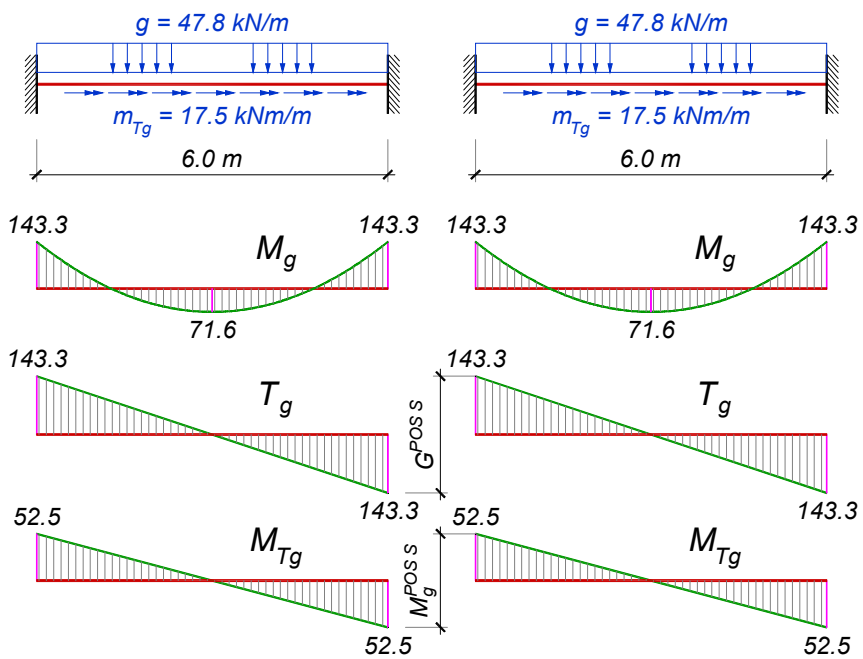


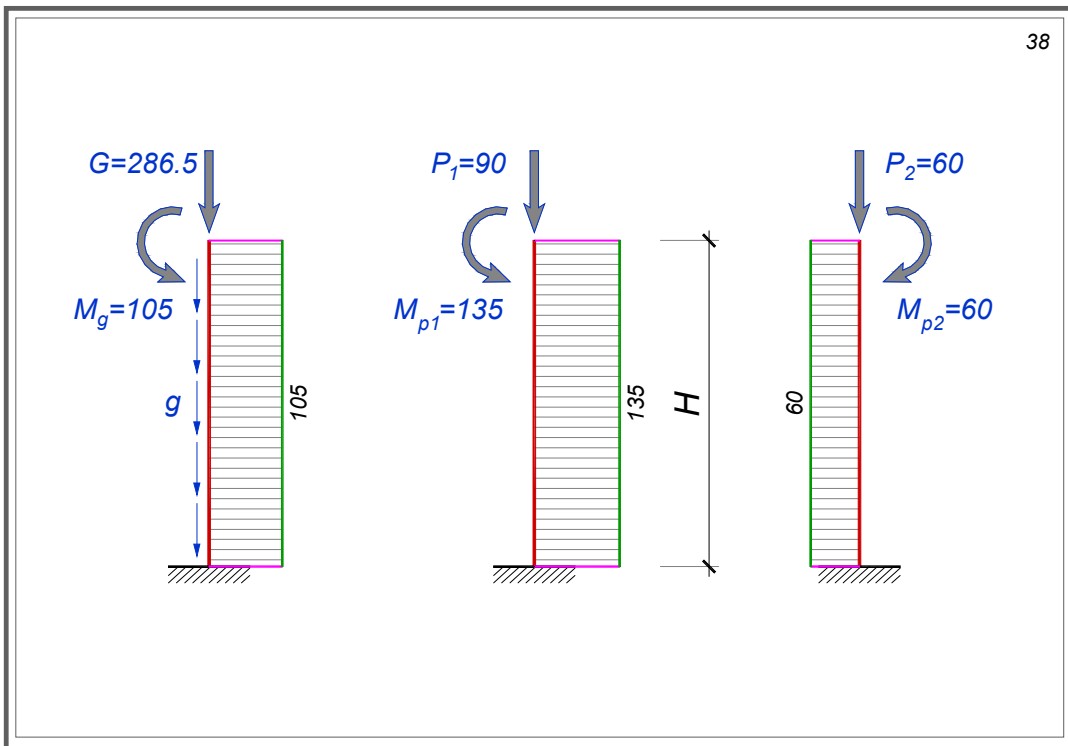
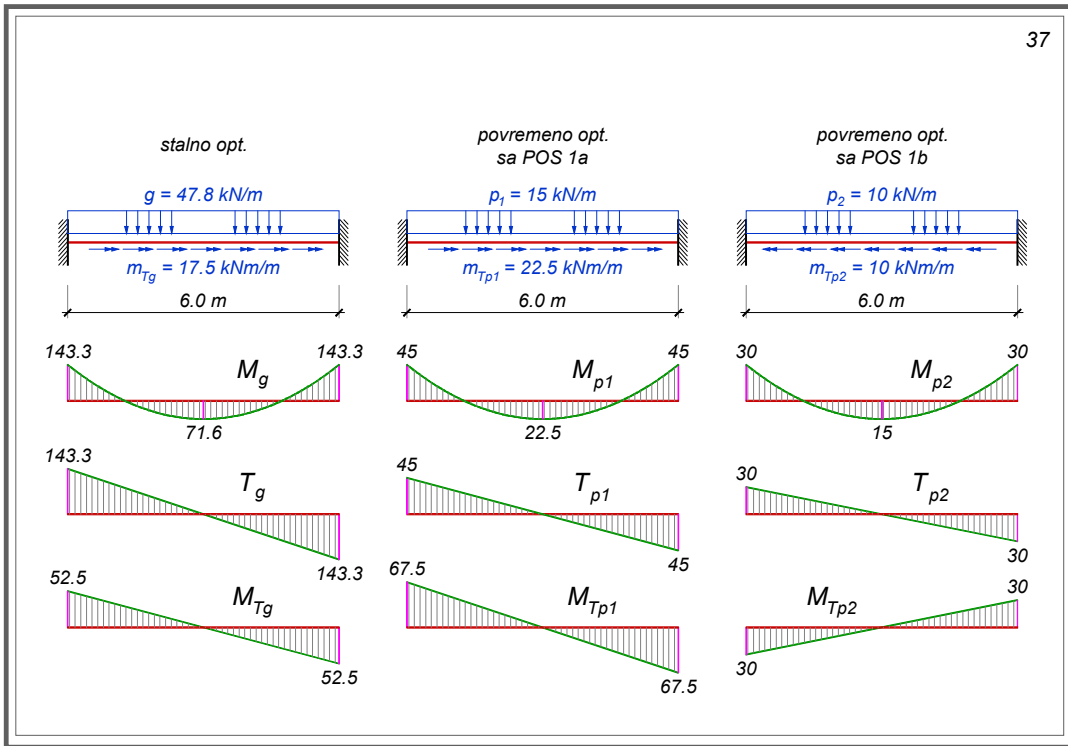
Proračun stuba POS S

35



36





3.2 DIMENZIONISANJE

Sa prethodnih dijagrama momenata je očito da leva strana stuba ne može biti zategnuta. Stoga se dimenzioniše samo desna strana, uzimajući u obzir stalno opterećenje i povremeno samo na ploči POS 1a.

$$M_u = 1.6 \times 105 + 1.8 \times 135 = 411 \text{ kNm}$$

$$N_u = 1.6 \times 286.5 + 1.8 \times 90 = 620.4 \text{ kN}$$

$$\text{pretp. } a_1 = 7 \text{ cm} \Rightarrow h = 85 - 7 = 78 \text{ cm}$$

$$M_{au} = 411 + 620.4 \times \left(\frac{0.85}{2} - 0.07 \right) = 631.2 \text{ kNm}$$

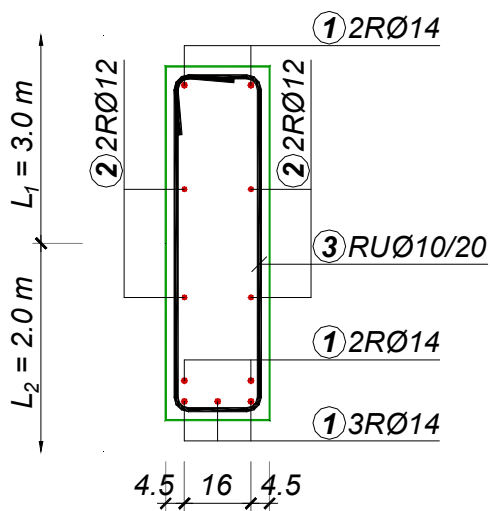
$$k = \frac{78}{\sqrt{\frac{631.2 \times 10^2}{25 \times 2.05}}} = 2.223 \Rightarrow \epsilon_b/\epsilon_a = 3.5/8.845\% ; \bar{\mu} = 22.952\%$$

$$A_{a,\text{potr.}} = 22.952 \times \frac{25 \times 78}{100} \times \frac{2.05}{40} - \frac{620.4}{40} = 7.43 \text{ cm}^2$$

$$A_{a,\text{min}} = \frac{0.2}{100} \times 25 \times 85 = 4.25 \text{ cm}^2 < A_{a,\text{potr.}}$$

usvojeno: **5RØ14** (7.70 cm²)

var. Ø < 16



var. Ø = 16

