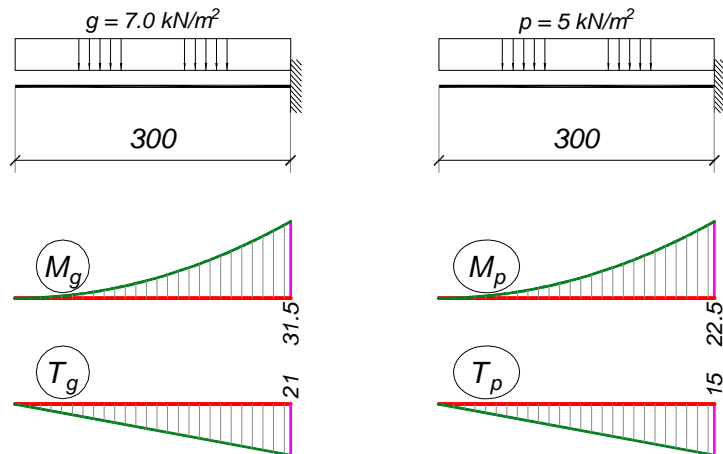


**POS 1a**

sopstvena teža ploče	$d_p \times g_b = 0.20 \times 25.0$	$= 5.0 \text{ kN/m}^2$
dodatno stalno opterečenje:	$Dg$	$= 2.0 \text{ kN/m}^2$
ukupno stalno opterečenje:	$g$	$= 7.0 \text{ kN/m}^2$
povremeno opterečenje:	$p =$	$= 5.0 \text{ kN/m}^2$

**POS 1a**

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

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

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

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

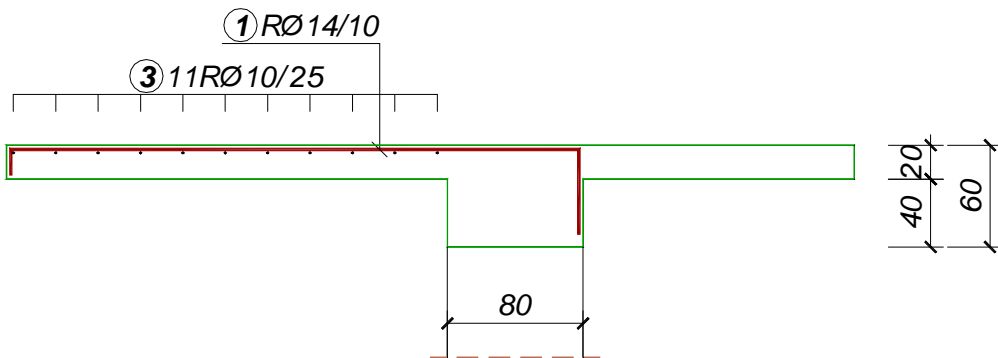
$$\mu = 16.826\%$$

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

usvojeno: **RØ 14/10** (15.40 cm<sup>2</sup>/m)

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

usvojeno: **RØ 10/25** (3.14 cm<sup>2</sup>/m)

**POS 1b**

sopstvena teža ploče

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

dodatno stalno opterečenje:

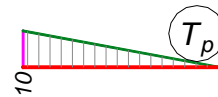
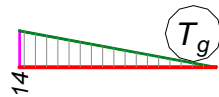
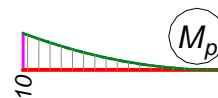
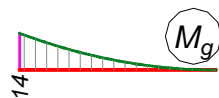
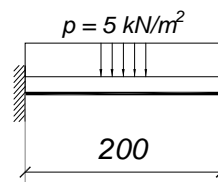
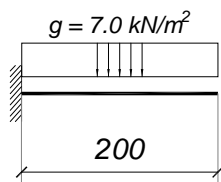
$$Dg = 2.0 \text{ kN/m}^2$$

ukupno stalno opterečenje:

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

povremeno opterečenje:

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



**POS 1b**

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

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

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

$$\mu = 7.151\%$$

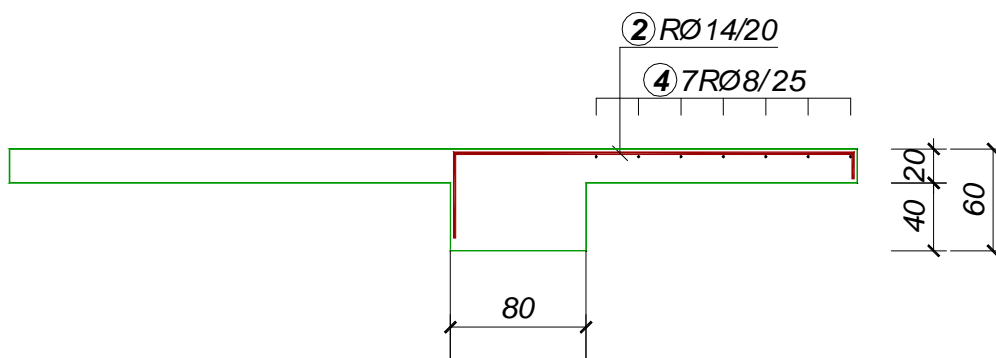
$$A_{a,\text{potr.}} = 7.151 \times 17 \times \frac{2.05}{40} = 6.23 \frac{\text{cm}^2}{\text{m}}$$

usvojeno: **RØ14/20** (7.70 cm<sup>2</sup>/m)

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

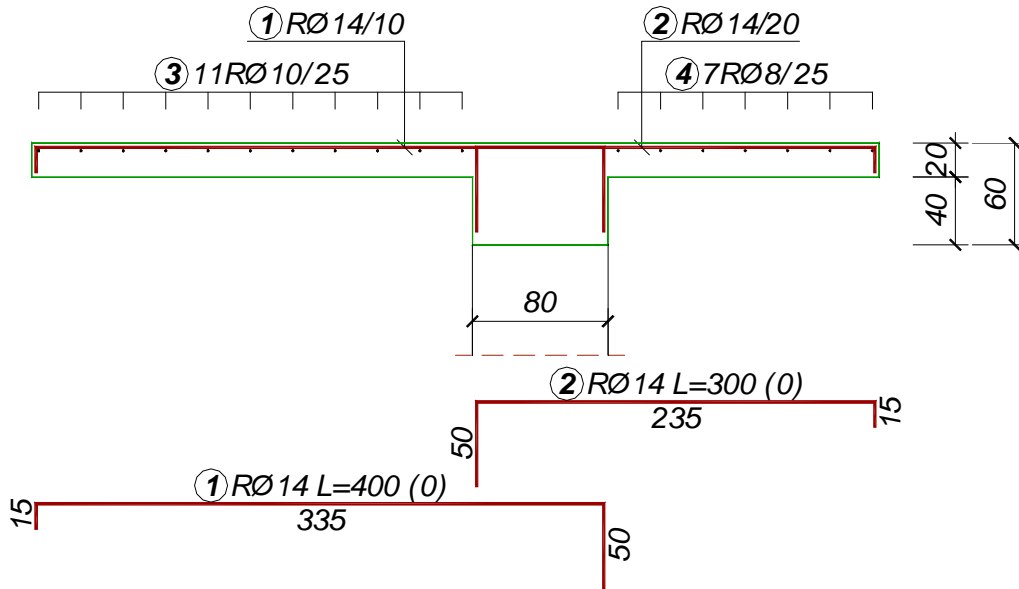
$$A_{ap,\text{min.}} = 0.085 \times 20 = 1.70 \text{ cm}^2/\text{m} > A_{ap,\text{potr.}}$$

usvojeno: **RØ8/25** (2.01 cm<sup>2</sup>/m)



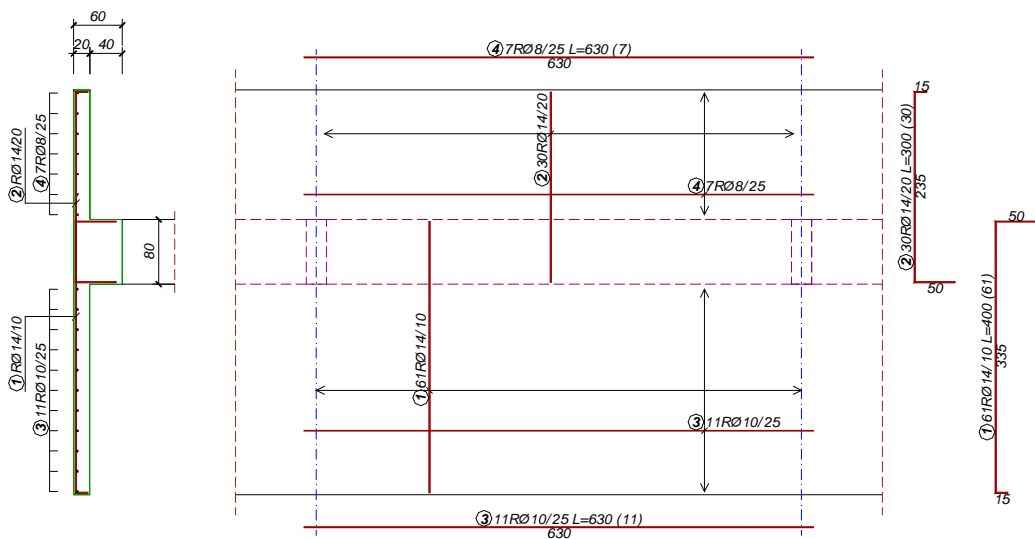
# Varijanta 1

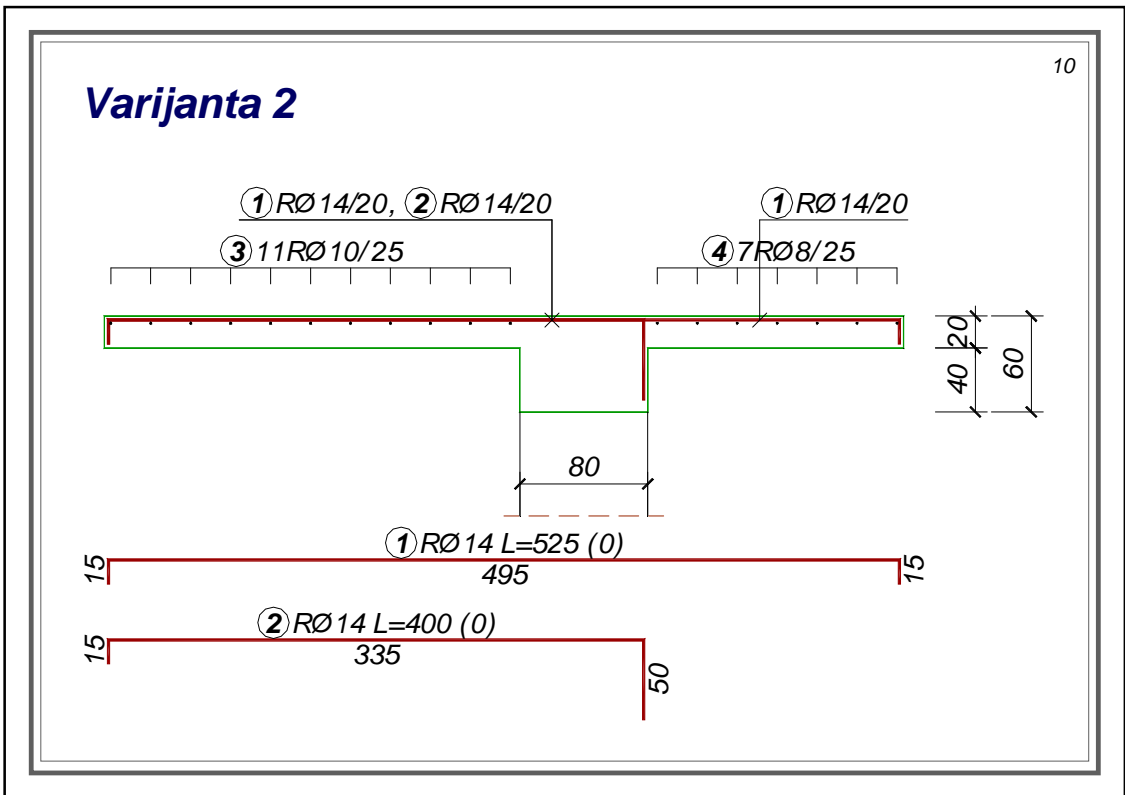
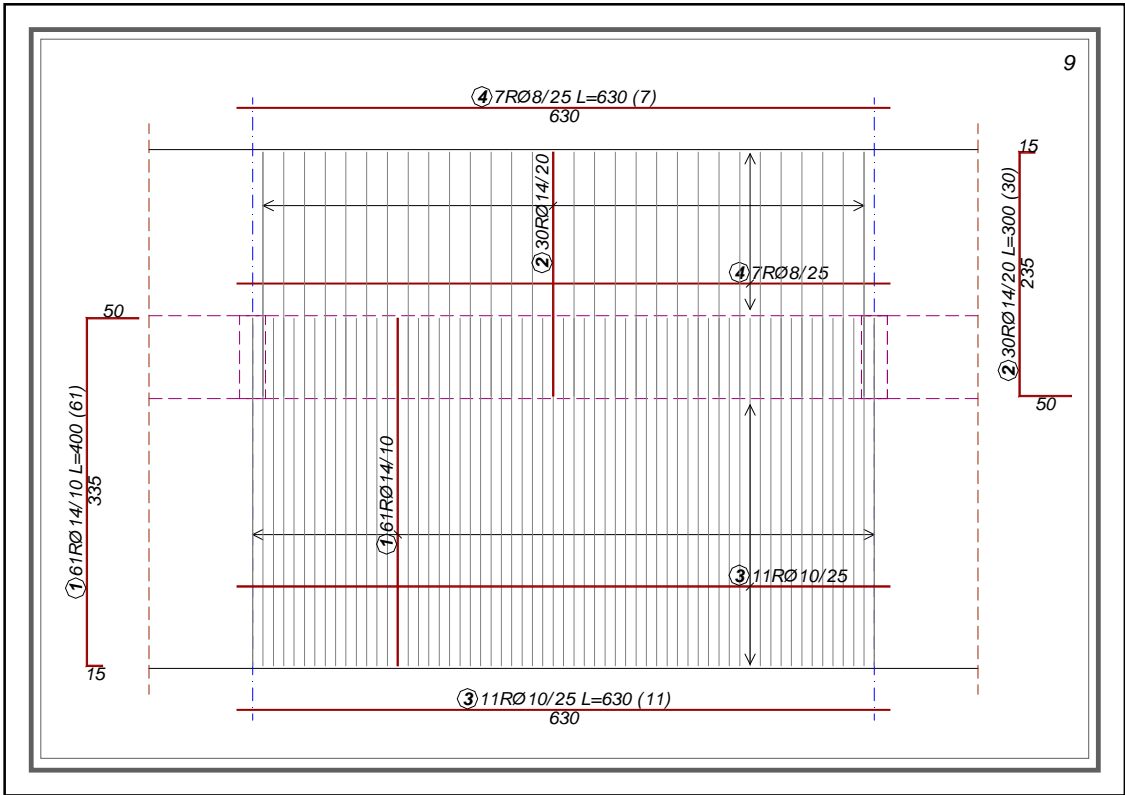
7



# Varijanta 1

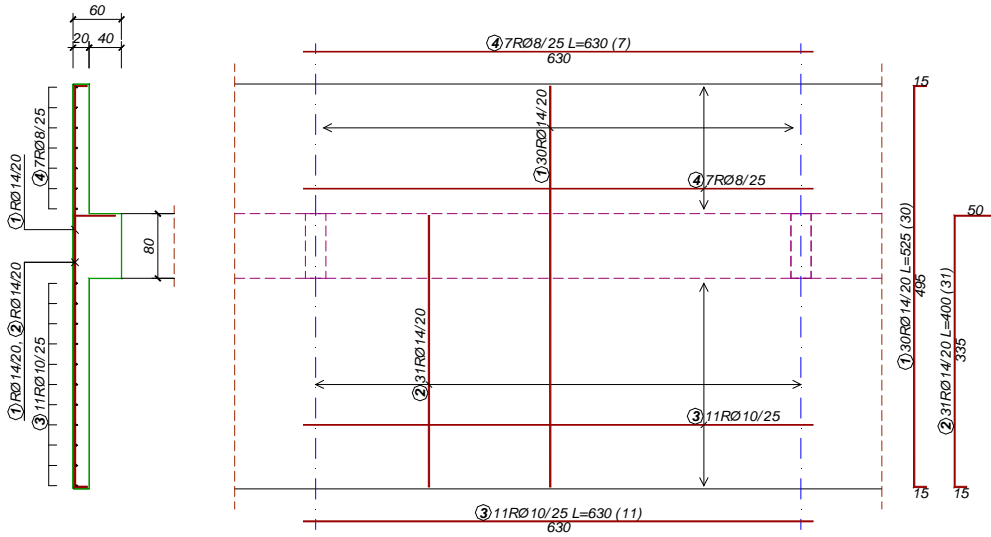
8



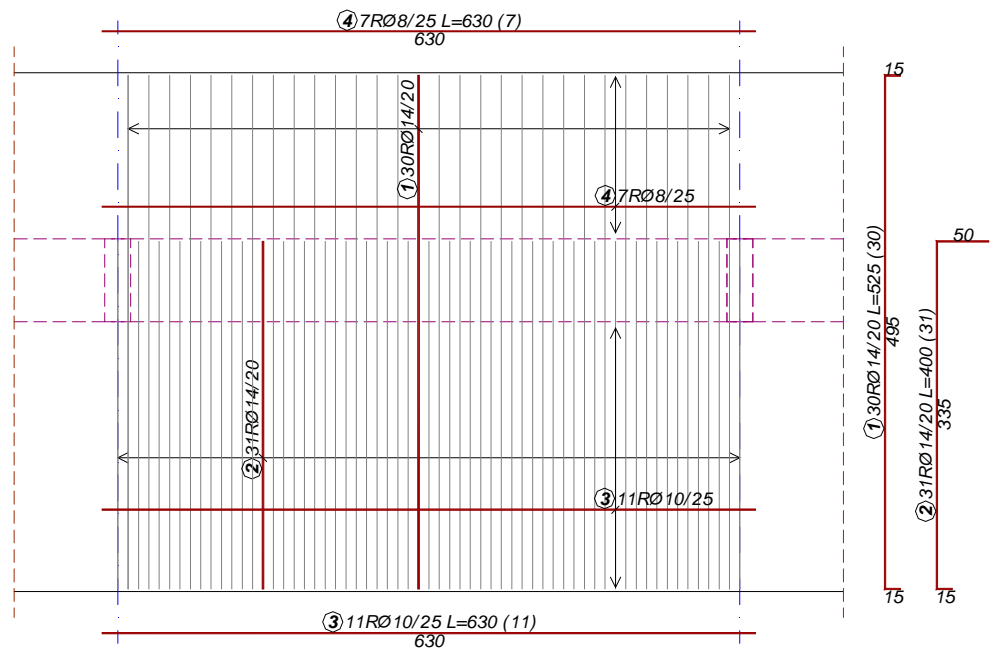


# Varijanta 2

11



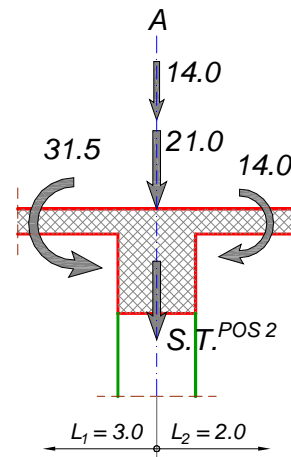
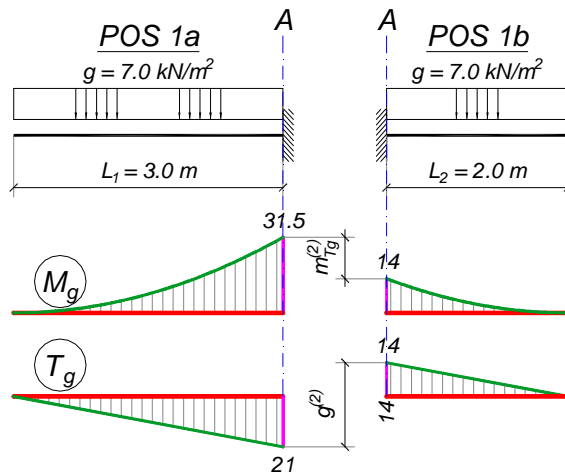
12



**POS 2***stalno opterećenje:*

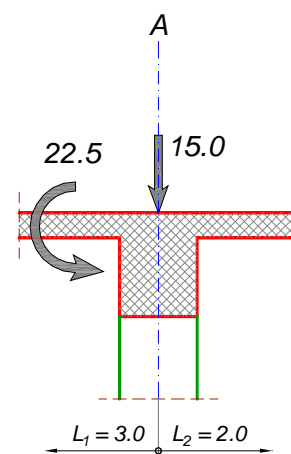
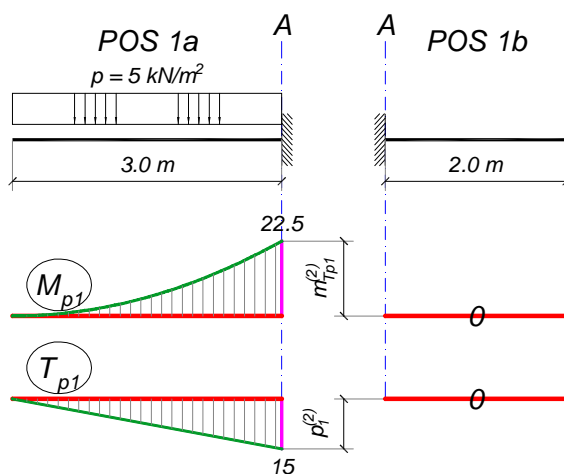
$$m_{Tg} = 31.5 - 14 = 17.5 \text{ kNm/m}$$

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

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

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

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

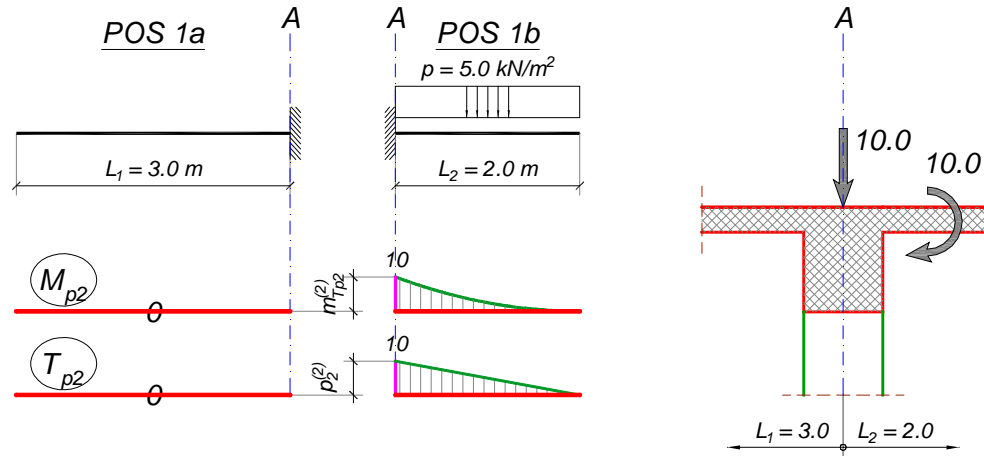


**POS 2**

povremeno opterećenje na POS 1b:

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

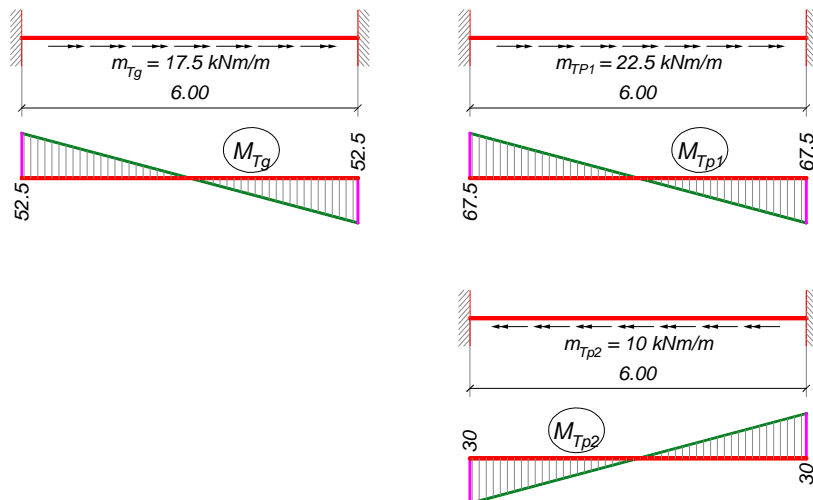
$$p_2 = 0 - (-10) = 10.0 \text{ kN/m}$$

**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  $M_T$**

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

$$MB 30 \text{ } \rho \text{ } t_r = 1.1 \text{ MPa}$$

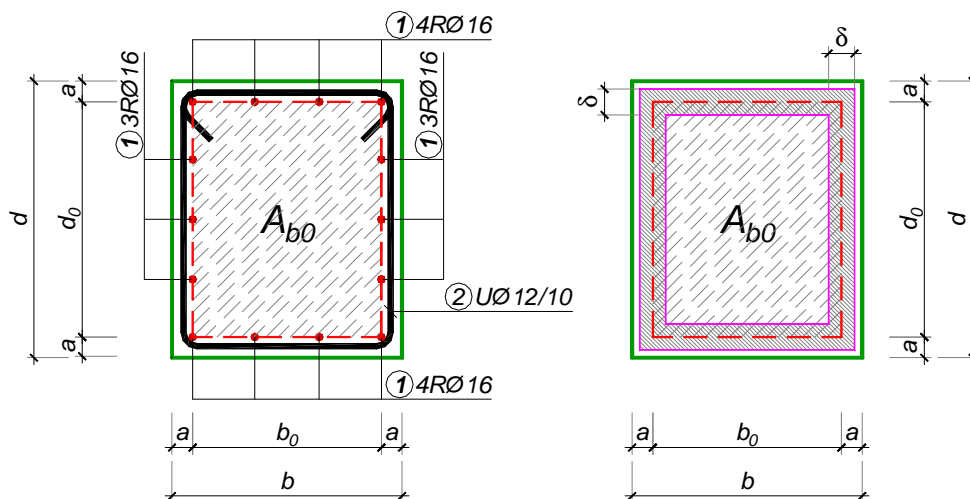
$$\tau_n^{M_T} = \frac{M_{Tu}}{2 \times A_{b0} \times \delta_0} = 0.44 \frac{\text{kN}}{\text{cm}^2} = 4\tau_r$$

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

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

**pretp.  $a = 4 \text{ cm}$ ,  $b \leq d$ :**

$$A_{b0} = b_0 \times d_0 = (b - 8) \times (d - 8)$$



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

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

<i>b</i>	<i>d</i>	<i>d usv.</i>
50	113.9	115
55	92.6	95
60	77.1	80
65	65.5	70

usvojeno:  $b / d = 80 / 60 \text{ cm}$

## 2.4 ANALIZA OPTEREĆENJA

### stalno opterećenje

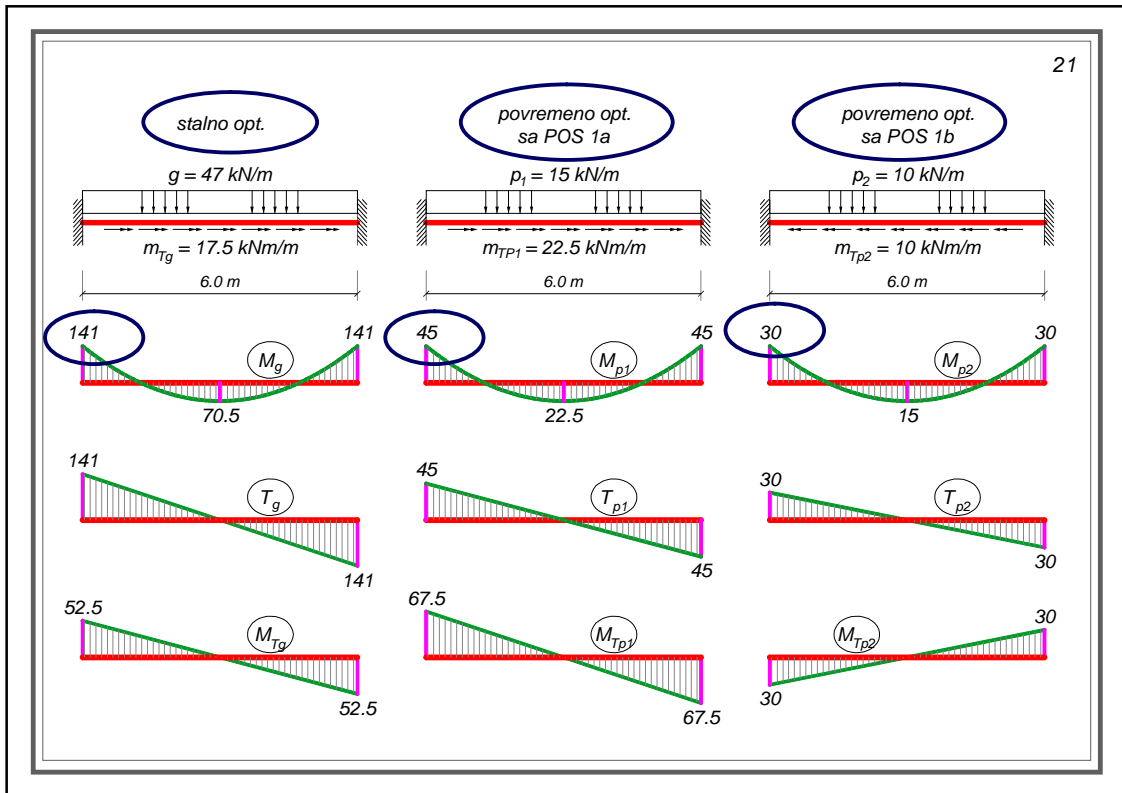
- sopstvena težina	$0.80 \times 0.60 \times 25$	= 12.0 kN/m
- od POS 1a, 1b		= 35.0 kN/m
ukupno, stalno opterećenje:	<i>g</i>	= 47.0 kN/m
raspodeljeni moment torzije	$m_{Tg}$	= 17.5 kNm/m

### povremeno opterećenje sa POS 1a

raspodeljeno opterećenje	$p_1$	= 15.0 kN/m
raspodeljeni moment torzije	$m_{Tp1}$	= 22.5 kNm/m

### povremeno opterećenje sa POS 1b

raspodeljeno opterećenje	$p_2$	= 10.0 kN/m
raspodeljeni moment torzije	$m_{Tp2}$	= -10.0 kNm/m



### 2.6.1 DIMENZIONISANJE 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.

presek nad osloncem

$$M_u = 1.6 \times 141 + 1.8 \times (45 + 30) = 360.6 \text{ kNm}$$

Pritisnuta je donja ivica nosača, pa je oblik pritisnute zone pravougaoni, širine  $b=80 \text{ cm}$ :

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

$$k = \frac{55}{\sqrt{\frac{360.6 \times 10^2}{80 \times 2.05}}} = 3.709 \Rightarrow \epsilon_b/\epsilon_a = 1.54/10\text{‰} ; \bar{\mu} = 7.638\%$$

$$A_{a,\text{potr.}} = 7.638 \times \frac{80 \times 55}{100} \times \frac{2.05}{40} = 17.22 \text{ cm}^2$$

presek u polju

$$M_u = 1.6 \times 70.5 + 1.8 \times (22.5 + 15) = 180.3 \text{ kNm}$$

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

$$B = \min. \left\{ \begin{array}{l} b + 20 \times d_p = 80 + 20 \times 20 = 480 \text{ cm} \\ b + 0.25 \times l_0 = 80 + 0.25 \times 0.6 \times 600 = 170 \text{ cm} \end{array} \right\} = 170 \text{ cm}$$

Pretpostavlja se da je neutralna linija u ploči. Sledi:

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

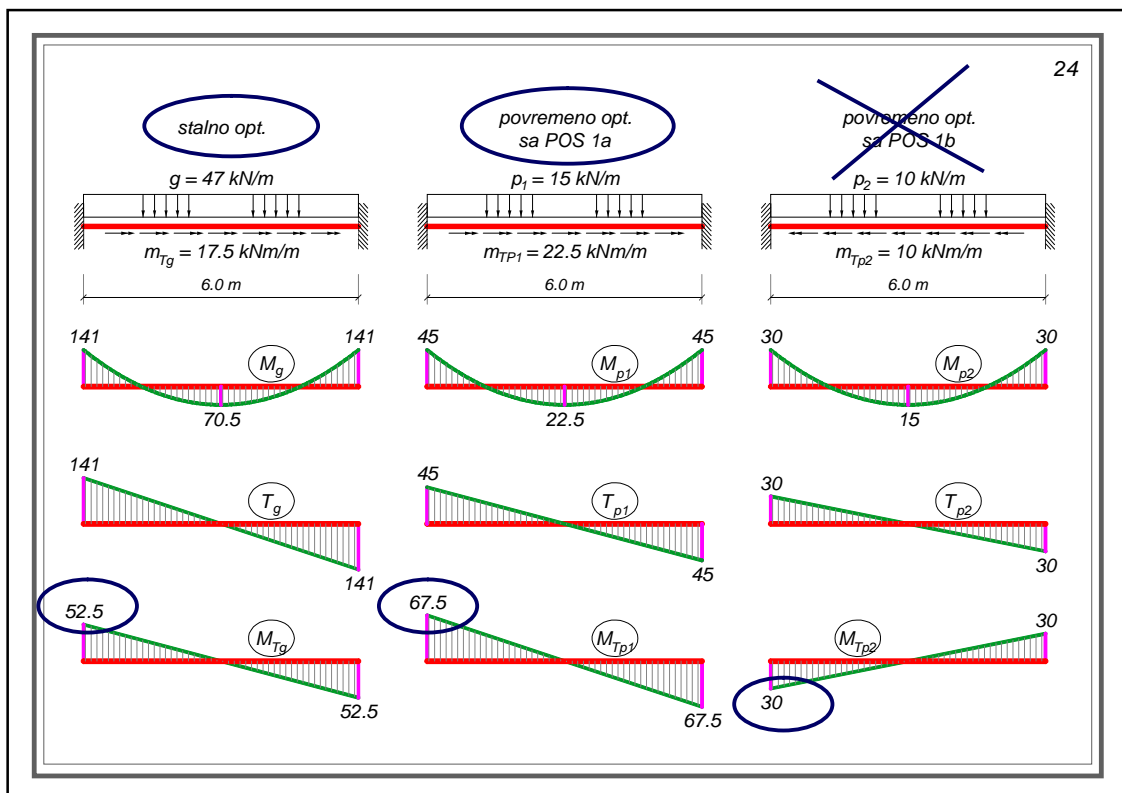
$$k = \frac{55}{\sqrt{\frac{180.3 \times 10^2}{170 \times 2.05}}} = 7.647 \Rightarrow \varepsilon_b/\varepsilon_a = 0.646/10\text{‰} ; \bar{\mu} = 1.747\% ; s = 0.061$$

$$x = 0.061 \times 55 = 3.34 \text{ cm} < d_p = 20 \text{ cm}$$

Pretpostavka o položaju neutralne linije je dobra, pa sledi:

$$A_{a,\text{potr.}} = 1.747 \times \frac{170 \times 55}{100} \times \frac{2.05}{40} = 8.37 \text{ cm}^2$$

$$A_{a,\text{min.}} = \mu_{\text{min}} \times b \times d = \frac{0.2}{100} \times 80 \times 60 = 9.6 \text{ cm}^2 > A_{a,\text{potr.}}$$



### 2.6.2.1 POVREMENO OPTEREĆENJE SAMO NA POS 1a

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

$$T_u = 1.6 \times 141 + 1.8 \times 45 = 306.6 \text{ kN}$$

$$A_{b0} = (80 - 2 \times 4) \times (60 - 2 \times 4) = 72 \times 52 = 3744 \text{ cm}^2$$

$$O_{b0} = 2 \times (72 + 52) = 248 \text{ cm}$$

$$\delta_0 = \frac{52}{8} = 6.5 \text{ cm} \Rightarrow \tau_{n(M_T)} = \frac{205.5 \times 10^2}{2 \times 3744 \times 6.5} = 0.422 \frac{\text{kN}}{\text{cm}^2}$$

$$z \approx 0.9 \times 55 = 49.5 \text{ cm} \Rightarrow \tau_{n(T)} = \frac{306.6}{80 \times 49.5} = 0.077 \frac{\text{kN}}{\text{cm}^2}$$

$$\tau_n = 0.422 + 0.077 = 0.5 \text{ kN/cm}^2 < 5 \tau_r = 0.55 \text{ kN/cm}^2$$

$$\lambda = \frac{L}{2} \times \left(1 - \frac{\tau_r}{\tau_n}\right) = \frac{600}{2} \times \left(1 - \frac{0.11}{0.5}\right) = 234 \text{ cm}$$

Osiguranje se vrši vertikalnim uzengijama i horizontalnom armaturom. Potrebna površina uzengija se sračunava iz odgovarajućih redukovanih uticaja ( $M_{TRu}$ , odnosno  $\tau_{Ru}$ ), posebno za uticaj momenta torzije, odnosno transverzalne sile<sup>2</sup>.

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

### 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:

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

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

$$\tau_{u,MIN}^T > \tau_{Ru(T)} = \tau_{n(T)} = 0.077 \text{ kN / cm}^2$$

Radi lakšeg poređenja rezultata proračuna za dve potencijalno merodavne kombinacije uticaja, potrebna površina uzengija potrebnih za prihvatanje transverzalne sile biće sračunata za  $m=2$ , bez obzira što će, zbog širine poprečnog preseka, svakako biti usvojene višesečne uzengije:

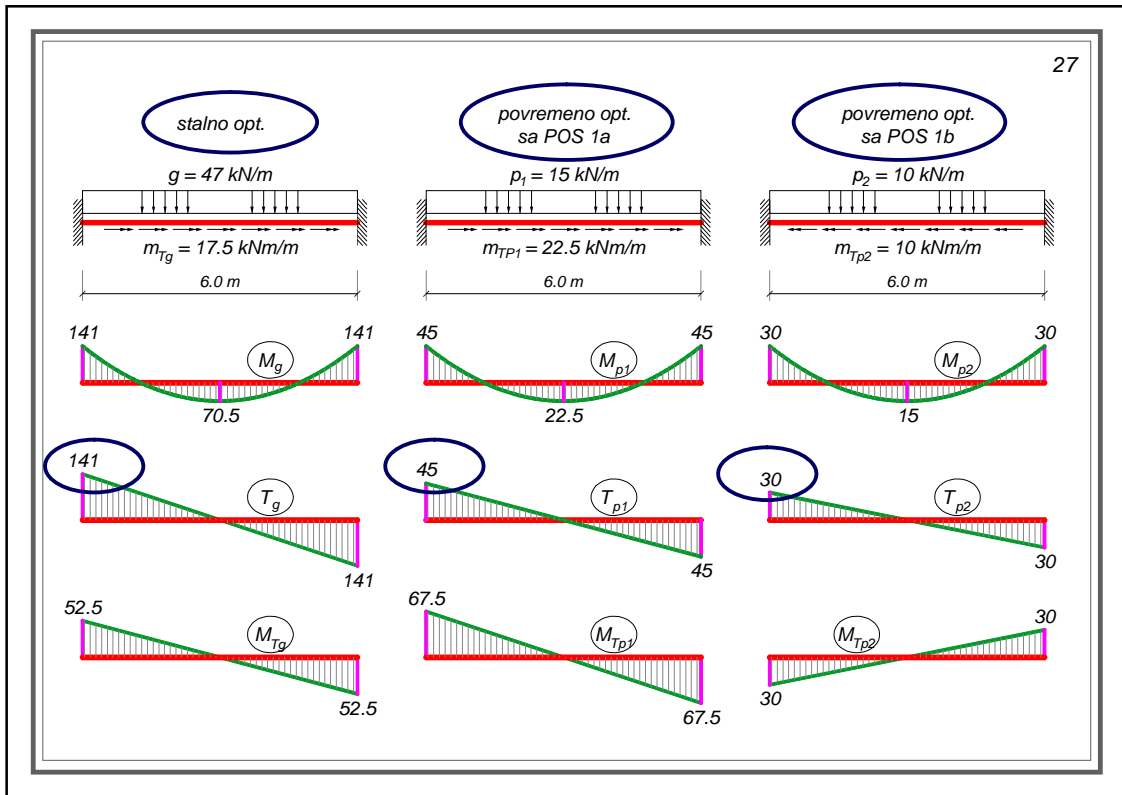
$$a_{u,T}^{(1)} = \frac{b \times \tau_{Ru}^T}{m \times \sigma_v} \times \frac{1}{(\cos \alpha + \sin \alpha \times \text{ctg} \theta)} \times e_u = \frac{80 \times 0.080}{2 \times 40} \times \frac{1}{(0 + 1 \times 1)} \times e_u = 0.080 \times e_u$$

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

### potrebna armatura za prihvatanje torzije

$$a_{u,M_T}^{(1)} = \frac{M_{TRu}}{2 \times A_{b0} \times \sigma_v} \times \tan \theta \times e_u = \frac{205.5 \times 10^2}{2 \times 3744 \times 40} \times 1.0 \times e_u = 0.069 \times e_u$$

$$\sum A_a = \frac{M_{Tu}}{2 \times A_{b0} \times \sigma_v} \times \cot \theta \times O_{b0} = \frac{205.5 \times 10^2}{2 \times 3744 \times 40} \times 1.0 \times 248 = 17.02 \text{ cm}^2$$



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2.6.2.2 POVREMENO OPTEREĆENJE ISTOVREMENO NA POS 1a i POS 1b

$$T_u = 1.6 \times 141 + 1.8 \times (45 + 30) = 360.6 \text{ kN} = \max T_u$$

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

$$\tau_{n(T)} = \frac{360.6}{80 \times 49.5} = 0.091 \frac{\text{kN}}{\text{cm}^2}$$

$$\tau_{n(M_r)} = \frac{151.5 \times 10^2}{2 \times 3744 \times 6.5} = 0.311 \frac{\text{kN}}{\text{cm}^2}$$

$$\tau_n = 0.311 + 0.091 = 0.402 \text{ kN/cm}^2 < 5 \tau_r = 0.55 \text{ kN/cm}^2$$

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

potrebna armatura za prihvatanje transverzalne sile

$$a_{u,T}^{(1)} = \frac{80 \times 0.091}{2 \times 40} \times \frac{1}{(0 + 1 \times 1)} \times e_u = 0.091 \times e_u$$

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

potrebna armatura za prihvatanje torzije

$$a_{u,M_r}^{(1)} = \frac{151.5 \times 10^2}{2 \times 3744 \times 40} \times 1.0 \times e_u = 0.051 \times e_u$$

$$\sum A_a = \frac{151.5 \times 10^2}{2 \times 3744 \times 40} \times 1.0 \times 248 = 12.54 < 17.02 \text{ cm}^2$$

### 2.6.3.1 USVAJANJE POPREČNE ARMATURE

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

$$a_u^{(1)} = a_{u,T}^{(1)} + a_{u,M_r}^{(1)} = (0.080 + 0.069) \times e_u = 0.149 \times e_u \quad (g + p_1)$$

$$a_u^{(1)} = a_{u,T}^{(1)} + a_{u,M_r}^{(1)} = (0.091 + 0.051) \times e_u = 0.142 \times e_u \quad (g + p_1 + p_2)$$

Usvajajući ČETVOROSEČNE uzengije za prihvatanje transversalne sile, sledi:

spoljašnja uzengija:

$$a_u^{(1)} = \frac{a_{u,T}^{(1)}}{2} + a_{u,M_r}^{(1)} = \left( \frac{0.080}{2} + 0.069 \right) \times e_u = 0.109 \times e_u$$

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

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

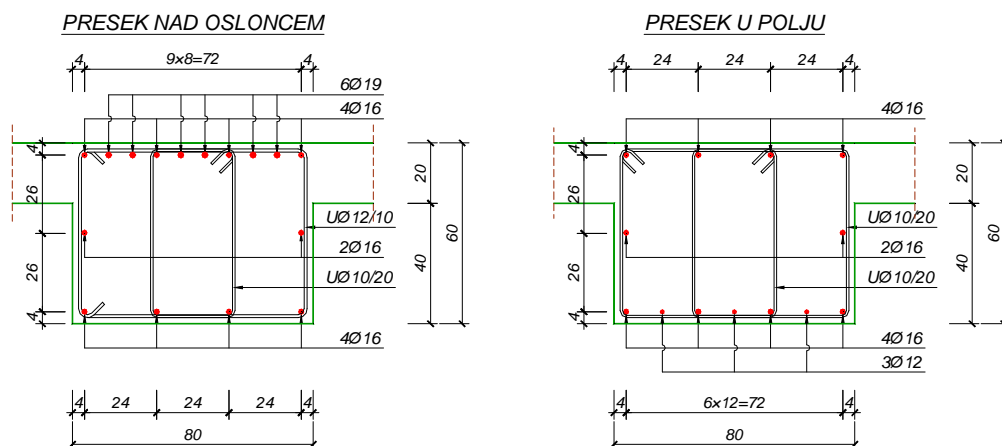
unutrašnja uzengija:

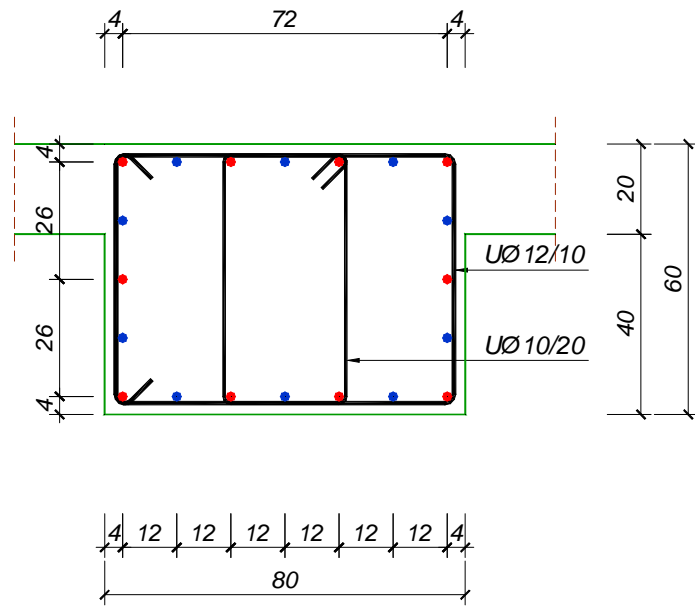
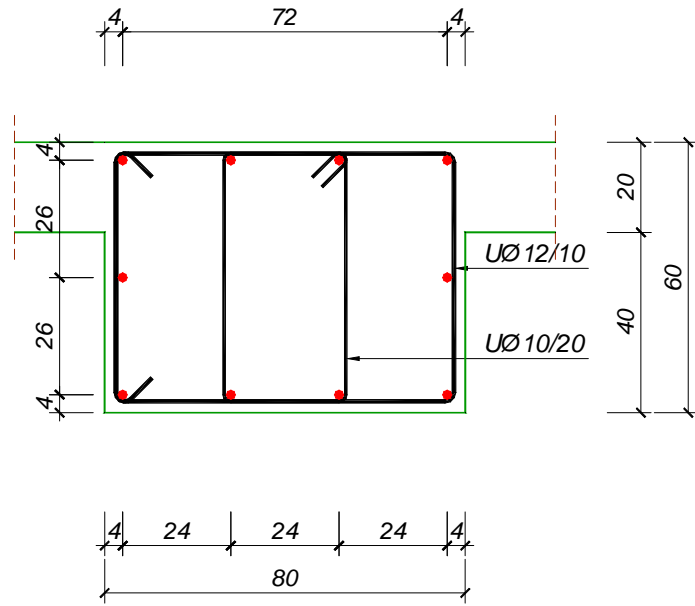
$$a_u^{(1)} = \frac{a_{u,T}^{(1)}}{2} = \frac{0.080}{2} \times e_u = 0.040 \times e_u$$

$$U\emptyset 10 \quad (a_u^{(1)} = 0.785 \text{ cm}^2) \Rightarrow e_u = 0.785 / 0.040 = 19.6 \text{ cm}$$

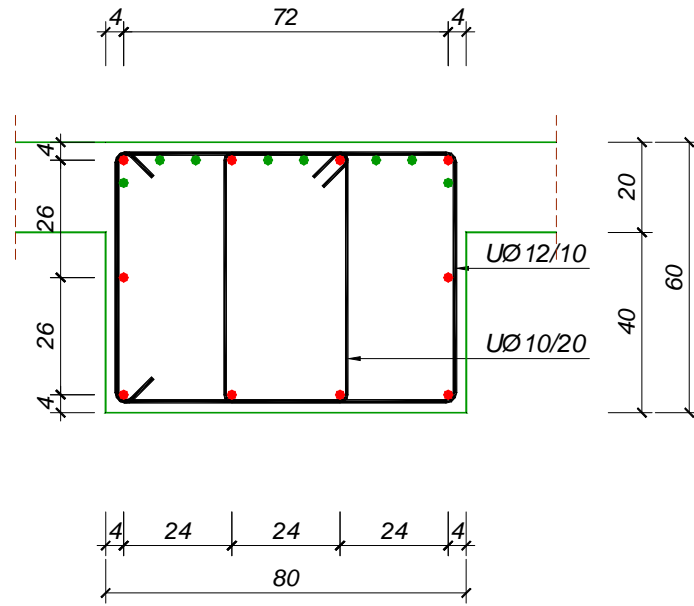
usvojeno: **U $\emptyset$ 10/20<sup>3</sup>**

$$\frac{a_u^{(1)}}{e_u} = \frac{1.13}{10} + \frac{0.785}{20} = 0.152 > 0.149$$

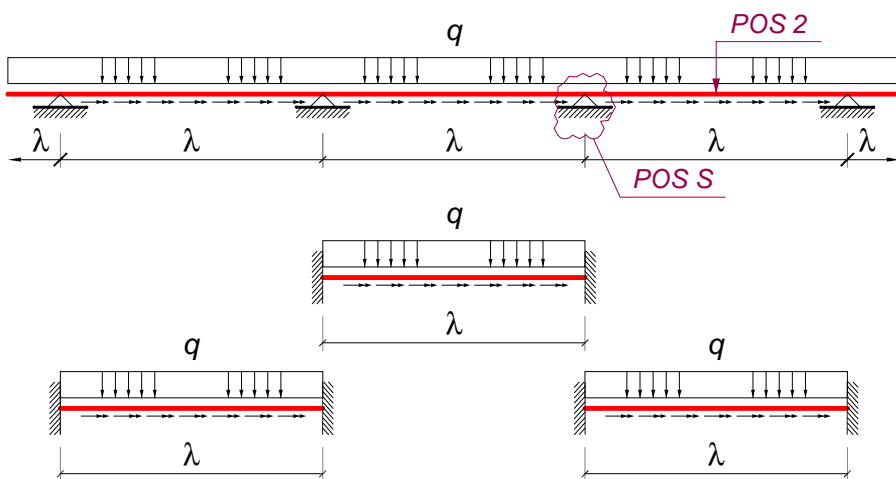


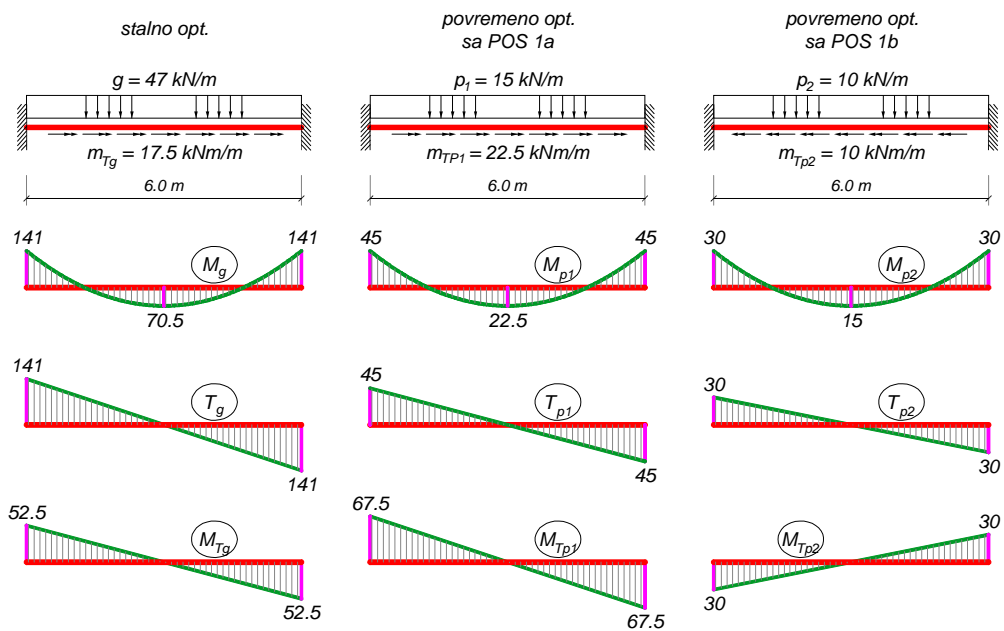
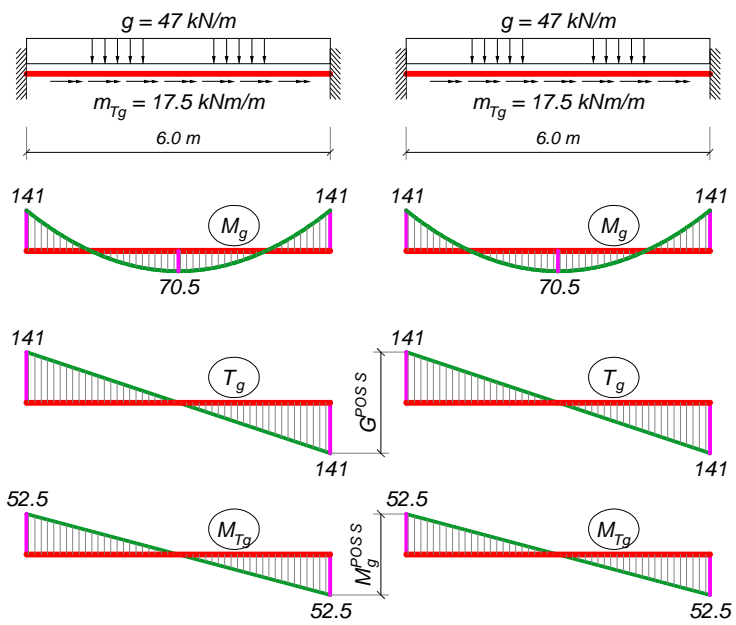


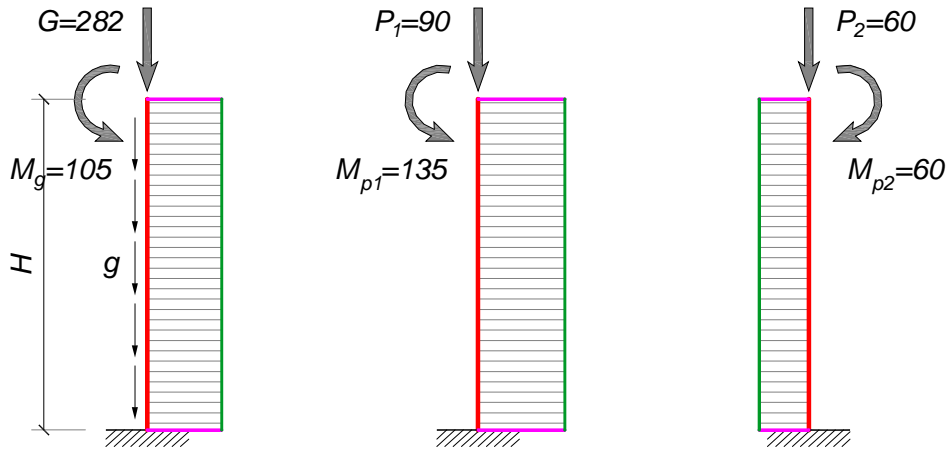




## Proračun stuba







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

$$N_u = 1.6 \times 282 + 1.8 \times 90 = 613.2 \text{ kN}$$

pretp.  $a_f = 7 \text{ cm} \Rightarrow h = 80 - 7 = 73 \text{ cm}$

$$M_{au} = 411 + 613.2 \times \left( \frac{0.8}{2} - 0.07 \right) = 613.4 \text{ kNm}$$

$$k = \frac{73}{\sqrt{\frac{613.4 \times 10^2}{25 \times 2.05}}} = 2.110 \Rightarrow \varepsilon_s / \varepsilon_a = 3.5 / 7.437\% ; \bar{\mu} = 25.907\%$$

$$A_{a, \text{potr.}} = 25.907 \times \frac{25 \times 73}{100} \times \frac{2.05}{40} - \frac{613.2}{40} = 8.90 \text{ cm}^2$$

usvojeno: **5Ø16** (10.05 cm<sup>2</sup>)

