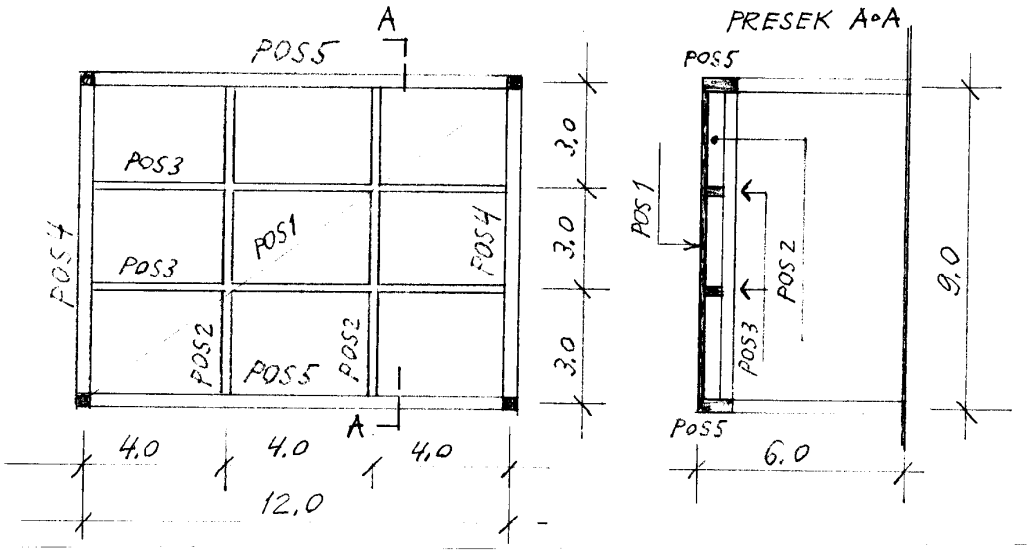
GRAĐEVINSKI FAKULTET
UNIVERZITET U BEOGRADU

Pismeni ispit 29.03.2008.

PROJEKTOVANJE I GRAĐENJE BETONSKIH KONSTRUKCIJA I



Za konstrukciju prikazanu na skici, za dejstvo totalnog opterećenja, potrebno je uraditi sledeće:

1. Dimenzionisati ploču POS 1 (dpl =14cm) u karakterističnim presecima.
2. Izvršiti analizu opterećenja, sračunati i nacrtati dijagrame statičkih uticaja za grede POS 2 i POS 3 (b/d=30/50 cm). Dozvoljeno je osrednjiti opterećenje na gredama.
3. Odrediti potrebnu armaturu greda POS 2 i POS 3. Nacrtati raspored armature u poprečnom preseku.
4. Izvršiti analizu opterećenja, sračunati i nacrtati dijagrame statičkih uticaja za grede POS 4 i POS 5 (b/d=40/100 cm).
5. Odrediti potrebnu armaturu greda POS 4 i POS 5.

Podaci za proračun:

MB 30, RA 400/500
p=5.0 kN/m^2

POS 1 *– ploča* d_p *= 14 cm*

$g = 0.14 \times 25 = 3.5\ kN/m^2$; $p = 5\ kN/m^2$

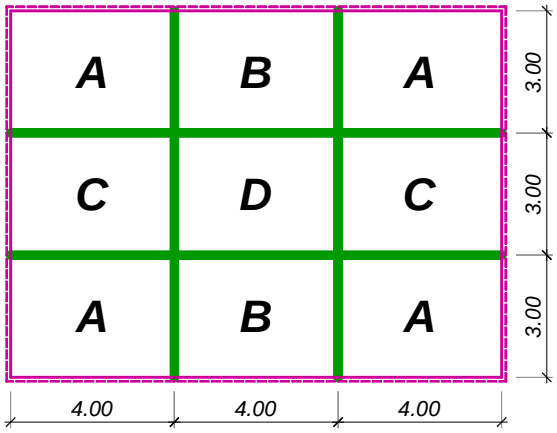
za sve delove ploče:

$L_y/L_x = 4.0/3.0 = 1.33 \approx 1.3$

$G = 3.5 \times 4.0 \times 3.0 = 42\ kN$

$P = 5.0 \times 4.0 \times 3.0 = 60\ kN$

$Q_u = 1.6 \times 42 + 1.8 \times 60 = 175.6\ kN$



ploča tipa ***»A«***

L_Y/L_X =	**1.3**		G	P	U	L	g_i	p_i
	k		kN	kN	kN	m	kN/m	kN/m
duža strana, uklještenje	0.346	**Q_1**	14.5	20.8		4.00	**3.63**	**5.19**
duža strana, oslonac	0.233	**Q_2**	9.8	14.0		4.00	**2.45**	**3.50**
kraća strana, uklještenje	0.244	**Q_3**	10.2	14.6		3.00	**3.42**	**4.88**
kraća strana, oslonac	0.177	**Q_4**	7.4	10.6		3.00	**2.48**	**3.54**
kraći pravac, polje	0.032	**M_X**	1.34	1.92	**5.61**	kNm/m		
duži pravac, polje	0.021	**M_Y**	0.88	1.26	**3.68**	kNm/m		
kraći pravac, oslonac	0.071	**X**	2.98	4.26	**12.44**	kNm/m		
duži pravac, oslonac	0.059	**Y**	2.48	3.54	**10.34**	kNm/m		

Q4
Q1 Q2
Q3

ploča tipa ***»B«***

L_Y/L_X =	**1.3**		G	P	U	L	g_i	p_i
	k		kN	kN	kN	m	kN/m	kN/m
duža strana, uklještenje	0.316	Q_1	13.3	19.0		4.00	**3.32**	**4.74**
duža strana, oslonac	0.218	Q_2	9.2	13.1		4.00	**2.29**	**3.27**
kraća strana, uklještenje	0.233	Q_3	9.8	14.0		3.00	**3.26**	**4.66**
kraći pravac, polje	0.028	M_X	1.18	1.68	**4.91**	kNm/m		
duži pravac, polje	0.022	M_Y	0.92	1.32	**3.85**	kNm/m		
kraći pravac, oslonac	0.063	X	2.65	3.78	**11.04**	kNm/m		
duži pravac, oslonac	0.055	Y	2.31	3.30	**9.64**	kNm/m		

Q3
Q1 Q2
Q3

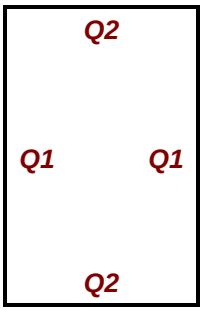
ploča tipa ***»C«***

L_Y/L_X =	**1.3**		G	P	U	L	g_i	p_i
	k		kN	kN	kN	m	kN/m	kN/m
duža strana, uklještenje	0.309	Q_1	13.0	18.5		4.00	**3.24**	**4.64**
kraća strana, oslonac	0.165	Q_2	6.9	9.9		3.00	**2.31**	**3.30**
kraća strana, uklještenje	0.217	Q_3	9.1	13.0		3.00	**3.04**	**4.34**
kraći pravac, polje	0.027	M_X	1.13	1.62	**4.73**	kNm/m		
duži pravac, polje	0.014	M_Y	0.59	0.84	**2.45**	kNm/m		
kraći pravac, oslonac	0.057	X	2.39	3.42	**9.99**	kNm/m		
duži pravac, oslonac	0.044	Y	1.85	2.64	**7.71**	kNm/m		

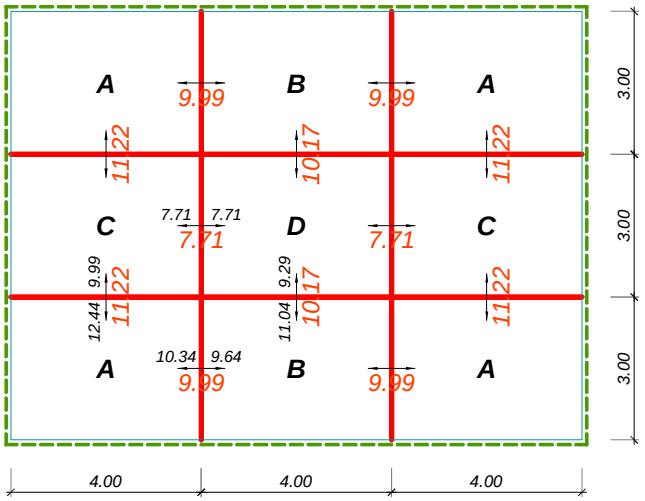
Q2
Q1 **Q1**
Q3

ploča tipa »D«

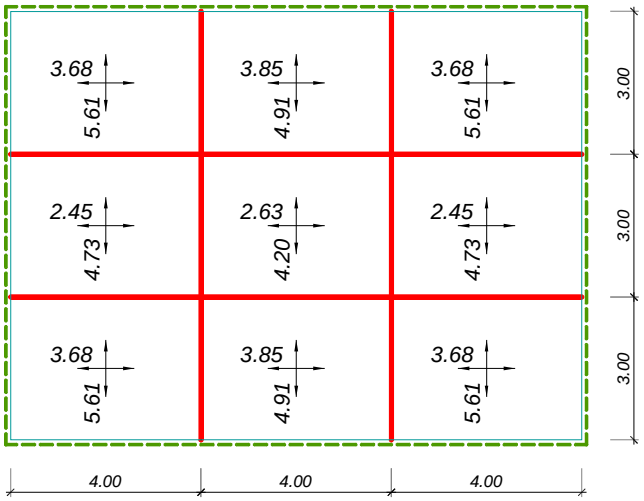
L_Y/L_X =	**1.3**		G	P	U	L	g_i	p_i
	k		kN	kN	kN	m	kN/m	kN/m
duža strana, uklještenje	0.291	Q_1	12.2	17.5		4.00	**3.06**	**4.37**
kraća strana, uklještenje	0.209	Q_2	8.8	12.5		3.00	**2.93**	**4.18**
kraći pravac, polje	0.024	M_X	1.01	1.44	**4.20**	kNm/m		
duži pravac, polje	0.015	M_Y	0.63	0.90	**2.63**	kNm/m		
kraći pravac, oslonac	0.053	X	2.23	3.18	**9.29**	kNm/m		
duži pravac, oslonac	0.044	Y	1.85	2.64	**7.71**	kNm/m		



M_u [kNm/m] - GORNJA ZONA



M_u [kNm/m] - DONJA ZONA



Dimenzionisanje

MB 30 Þ $f_B = 20.5$ MPa ; RA 400/500 Þ $s_V = 400$ MPa

$max.M_u = M_{yu} = 11.22$ kNm/m (upravno na POS 3 - oslonac između ploča A i C)

$a_{1y} = 2.5$ cm Þ $h_y = d - a_{1y} = 14 - 2.5 = 11.5$ cm

$$k = \frac{11.5}{\sqrt{\frac{11.22 \times 10^2}{100 \times 2.05}}} = 4.916 \quad \Rightarrow \quad e_b/e_a = 1.075/10‰ \; ; \; \bar{\mu} = 4.285\%$$

$$A_{aY} = 4.285 \times \frac{100 \times 11.5}{100} \times \frac{2.05}{40} = 2.53 \text{ cm}^2/\text{m} > A_{a,min.} = 0.1 \times 14 = 1.4 \text{ cm}^2/\text{m}$$

pretp. Ø8 ($a_a^{(1)} = 0.503$ cm²/m) $\Rightarrow$ $e_a = \frac{100 \times a_a^{(1)}}{A_a} = \frac{100 \times 0.503}{2.53} = 19.9$ cm

usvojeno: **RØ8/15** (3.35 cm²/m)

$A_{ap} = 0.2 \times 2.53 = 0.51 \text{ cm}^2/\text{m} < A_{ap,min.} = 0.085 \times 14 = 1.19 \text{ cm}^2/\text{m}$

pretp. Ø8 ($a_{ap}^{(1)} = 0.503$ cm²/m) $\Rightarrow$ $e_{ap} = \frac{100 \times a_{ap}^{(1)}}{A_{ap}} = \frac{100 \times 0.503}{1.19} = 42.2$ cm

usvojeno: **RØ8/30** (1.68 cm²/m)

$max.M_{xu}$ = 9.99 kNm/m (upravno na POS 2 - oslonac između ploča A i B)

$h_x = h_y - (Ø_x+Ø_y)/2 = 11.5 - 0.8 = 10.7$ cm

$$k = \frac{10.7}{\sqrt{\frac{9.99\times10^2}{100\times2.05}}} = 4.847 \quad \Rightarrow \quad e_b/e_a = 1.094/10‰ \quad ; \quad \bar{\mu} = 4.409\%$$

$$A_{aX} = 4.847\times\frac{100\times10.7}{100}\times\frac{2.05}{40} = 2.44\ cm^2/m > A_{a,min.} = 0.1\times14 = 1.4\ cm^2/m$$

usvojeno: **RØ8/15** (3.35 cm^2/m)

usvojeno: **RØ8/30** (1.68 cm^2/m) – podeona armatura

S obzirom na veoma male vrednosti graničnih računskih momenata savijanja u donjoj zoni, biće usvojena minimalna armatura. Minimalni raspoloživi profil armature je RØ8 a maksimalno dopušteno rastojanje šipki 20 cm, pa sledi:

$$RØ8/20 \Rightarrow A_a = \frac{100\times a_a^{(1)}}{e_a} = \frac{100\times0.503}{20} = 2.51\frac{cm^2}{m} > A_{a,min.} = 0.1\times14 = 1.4\ cm^2/m$$

Nosivost ovako usvojene armature, sračunato sa približnom vrednošću kraka unutrašnjih sila koji odgovara manjoj statičkoj visini z ≈ 0.9×10.7 = 9.63 cm, je:

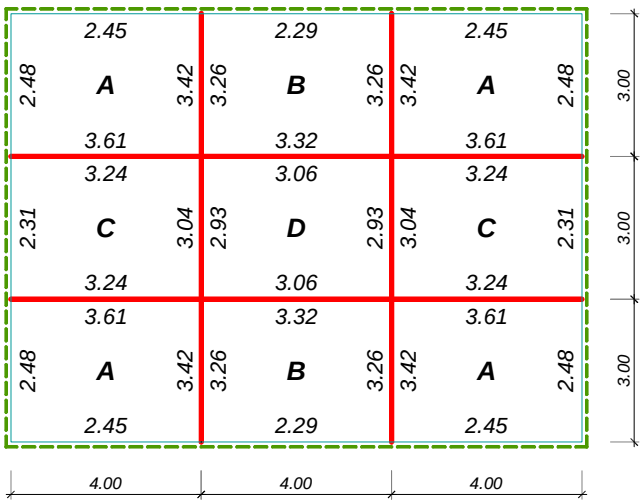
$M_u \approx 2.51\times9.63\times10^{-2}\times40 = 9.68$ kNm/m > $M_{u,max}$ = 5.61 kNm/m

usvojeno: **RØ8/20** (2.51 cm^2/m) - donja zona, oba pravca

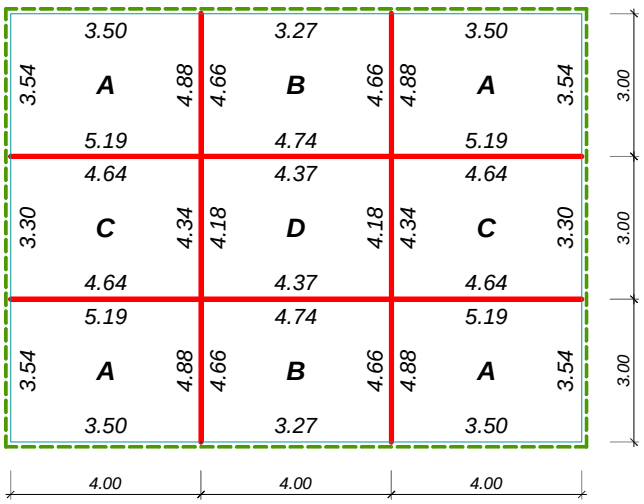
POS 2, POS 3 *– grede b/d = 30/50 cm*

Opterećenje sa POS 1 na pojedine grede:

STALNO OPTERECENJE [kN/m]



POVREMENO OPTERECENJE [kN/m]



Sopstvenu težinu greda POS 2 i POS 3, odnosno POS 4 i POS 5:

$g_{2,3}$ = 0.3×0.5×25 = 3.75 kN/m $g_{4,5}$ = 0.4×1.0×25 = 10.0 kN/m

treba dodati prikazanom stalnom opterećenju sa POS 1.

Ovako sračunata opterećenja po pojedinim poljima će, prema uslovu zadatka, biti osrednjena posebno za svaku pojedinačnu gredu.

grede POS 2:

$g_1 = 3.42 + 3.26 + 3.75 = 10.43\ kN/m = g_3$; $p_1 = 4.88 + 4.66 = 9.54\ kN/m = p_3$

$g_2 = 3.04 + 2.93 + 3.75 = 9.72\ kN/m$; $p_2 = 4.34 + 4.18 = 8.52\ kN/m$

$$g^{POS2} = \frac{2 \times 10.43 + 9.72}{3} = 10.19\ kN/m \quad ; \quad p^{POS2} = \frac{2 \times 9.54 + 8.52}{3} = 9.2\ kN/m$$

grede POS 3:

$g_1 = 3.24 + 3.61 + 3.75 = 10.6\ kN/m = g_3$; $p_1 = 5.19 + 4.64 = 9.83\ kN/m = p_3$

$g_2 = 3.06 + 3.32 + 3.75 = 10.13\ kN/m$; $p_2 = 4.74 + 4.37 = 9.11\ kN/m$

$$g^{POS3} = \frac{2 \times 10.6 + 10.13}{3} = 10.44\ kN/m \quad ; \quad p^{POS3} = \frac{2 \times 9.83 + 9.11}{3} = 9.59\ kN/m$$

grede POS 4:

$g_1 = 2.48 + 10.0 = 12.48\ kN/m = g_3$; $p_1 = 3.54\ kN/m = p_3$

$g_2 = 2.31 + 10.0 = 12.31\ kN/m$; $p_2 = 3.30\ kN/m$

$$g^{POS4} = \frac{2 \times 12.48 + 12.31}{3} = 12.42\ kN/m \quad ; \quad p^{POS4} = \frac{2 \times 3.54 + 3.30}{3} = 3.46\ kN/m$$

grede POS 5:

$g_1 = 2.45 + 10.0 = 12.45\ kN/m = g_3$; $p_1 = 3.50\ kN/m = p_3$

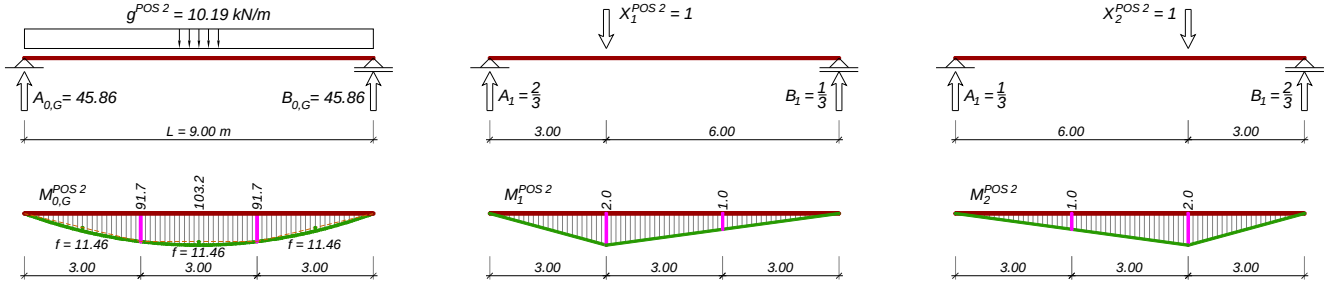
$g_2 = 2.29 + 10.0 = 12.29\ kN/m$; $p_2 = 3.27\ kN/m$

$$g^{POS5} = \frac{2 \times 12.45 + 12.29}{3} = 12.40\ kN/m \quad ; \quad p^{POS5} = \frac{2 \times 3.50 + 3.27}{3} = 3.42\ kN/m$$

Kod izbora statičkog sistema za proračun greda POS 2 do POS 5, treba zapaziti sledeće:

- *konstrukcija se oslanja samo na 4 ugaona stuba, pa se mora sračunati kao roštiljna;*
- *grede POS 2 i POS 3 (b/d=30/50 cm) su daleko manje krutosti od greda POS 4 i POS 5 (b/d=40/100 cm). Stoga se može smatrati da su grede POS 4 i POS 5 vertikalni oslonci za POS 2 i POS 3;*
- *Torziona krutost greda POS 4 i POS 5 određena je prvenstveno manjom dimenzijom preseka i nije realno da, naročito u stanju sa prslinama, ove grede predstavljaju uklještenja (potpuno spreče rotaciju) krajeva greda POS 2 i POS 3. Slično, ove grede ne mogu jedna drugoj predstavljati uklještenje niti biti uklještene u stubove datih dimenzija (sa crteža očito 40/40 cm) pa sledi da su POS 4 i POS 5 proste grede raspona 9.0 odnosno 12.0 m, opterećene opterećenjem sa ploče POS 1 i u trećinama raspona reakcijama greda POS 3, odnosno POS 2.*
- *grede POS 2 i POS 3 su iste krutosti, opterećene približno jednakim opterećenjem ali različitih raspona, pa se moraju proračunati kao roštiljna konstrukcija. Kao statički nepoznate se usvajaju vertikalne sile u presečnim tačkama, a sračunavaju se metodom sila, izjednačavanjem deformacija presečnih tačaka. Zbog simetrije je jasno da su sve nepoznate sile X_i jednake.*

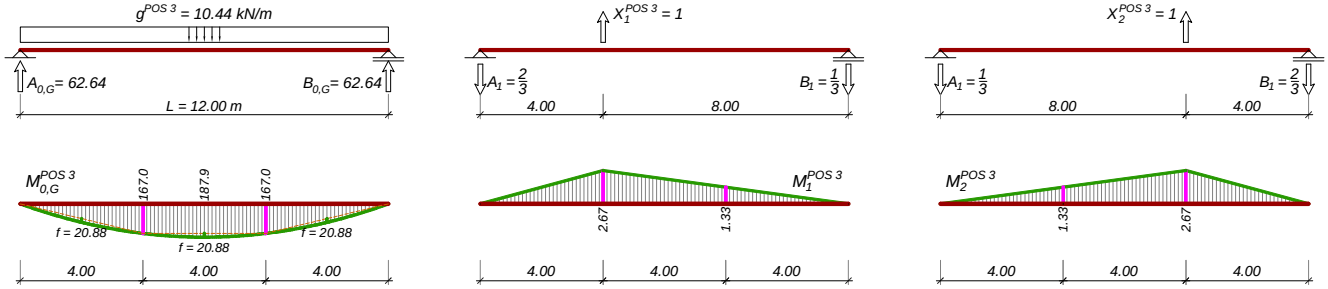
U nastavku je prikazan proračun statičkih uticaja za grede POS 2 i POS 3 i prikazani dijagrami momenata savijanja i transverzalnih sila usled stalnog (G), povremenog (P) i graničnog računskog (U) opterećenja.



$$EI\delta_{11}^{POS2} = \frac{9.0}{3} \times 2.0^2 = 12.0 = EI\delta_{22}^{POS2}$$

$$EI\delta_{12}^{POS2} = 2 \times \frac{3.0}{3} \times 2.0 \times 1.0 + \frac{3.0}{6} \times \left[2.0 \times (2 \times 1.0 + 2.0) + 1.0 \times (2 \times 2.0 + 1.0)\right] = 10.5 = EI\delta_{21}^{POS2}$$

$$EI\delta_{10,G}^{POS2} = \frac{3.0}{3} \times (91.7 \times 2.0 + 91.7 \times 1.0) + \frac{3.0}{3} \times 11.46 \times (1.0 + 2.0) + \frac{3.0}{2} \times 91.7 \times (2.0 + 1.0) +$$
$$+ \frac{3.0}{3} \times 11.46 \times (2.0 + 1.0) = 275.1 + 34.4 + 412.7 + 34.4 = 756.6 = EI\delta_{20,G}^{POS2}$$



$$EI\delta_{11}^{POS3} = \frac{12.0}{3} \times 2.67^2 = 28.44 = EI\delta_{22}^{POS3}$$

$$EI\delta_{12}^{POS3} = 2 \times \frac{4.0}{3} \times 2.67 \times 1.33 + \frac{4.0}{6} \times \left[2.67 \times (2 \times 1.33 + 2.67) + 1.33 \times (2 \times 2.67 + 1.33)\right] = 24.89$$

$$-EI\delta_{10,G}^{POS3} = \frac{4.0}{3} \times (167.0 \times 2.67 + 167.0 \times 1.33) + \frac{4.0}{3} \times 20.88 \times (1.33 + 2.67) +$$
$$+ \frac{4.0}{2} \times 167.0 \times (2.67 + 1.33) + \frac{4.0}{3} \times 20.88 \times (2.67 + 1.33) =$$
$$= 890.9 + 111.4 + 1336.3 + 111.4 = 2449.9 = -EI\delta_{20,G}^{POS3}$$

$$EI\delta_{11} = EI\delta_{11}^{POS2} + EI\delta_{11}^{POS3} = 12.0 + 28.44 = 40.44 = EI\delta_{22}$$

$$EI\delta_{12} = EI\delta_{12}^{POS2} + EI\delta_{12}^{POS3} = 10.5 + 24.89 = 35.39 = EI\delta_{21}$$

$$EI\delta_{10,G} = EI\delta_{10,G}^{POS2} + EI\delta_{10,G}^{POS3} = 756.6 - 2449.9 = -1693.3 = EI\delta_{20,G}$$

$$\left.\begin{aligned} EI\delta_{11} \cdot X_{1G} + EI\delta_{12} \cdot X_{2G} + EI\delta_{10,G} = 0 \\ EI\delta_{21} \cdot X_{1G} + EI\delta_{22} \cdot X_{2G} + EI\delta_{20,G} = 0 \end{aligned}\right\} \Rightarrow X_{1G} = -\frac{-1693.3}{40.44 + 35.39} = 22.33\,kN = X_{2G}$$

Sile koje se prenose na POS 5 (sa POS 2), odnosno POS 4 (sa POS 3):

$$G^{POS2} = 45.86 + {}^{2}\!/_{3} \times 22.33 + {}^{1}\!/_{3} \times 22.33 = 68.18\,kN$$
$$G^{POS3} = 62.64 + \left(-{}^{2}\!/_{3}\right) \times 22.33 + \left(-{}^{1}\!/_{3}\right) \times 22.33 = 40.31\,kN$$

Analogno se proračunavaju uticaji usled povremenog opterećenja:

$$EI\delta_{10,P}^{POS2} = \frac{p_2}{g_2} \times EI\delta_{10,G}^{POS2} = \frac{9.20}{10.19} \times 756.6 = 683.1$$

$$EI\delta_{10,P}^{POS3} = \frac{p_3}{g_3} \times EI\delta_{10,G}^{POS3} = \frac{9.59}{10.44} \times (-2449.9) = -2250.5$$

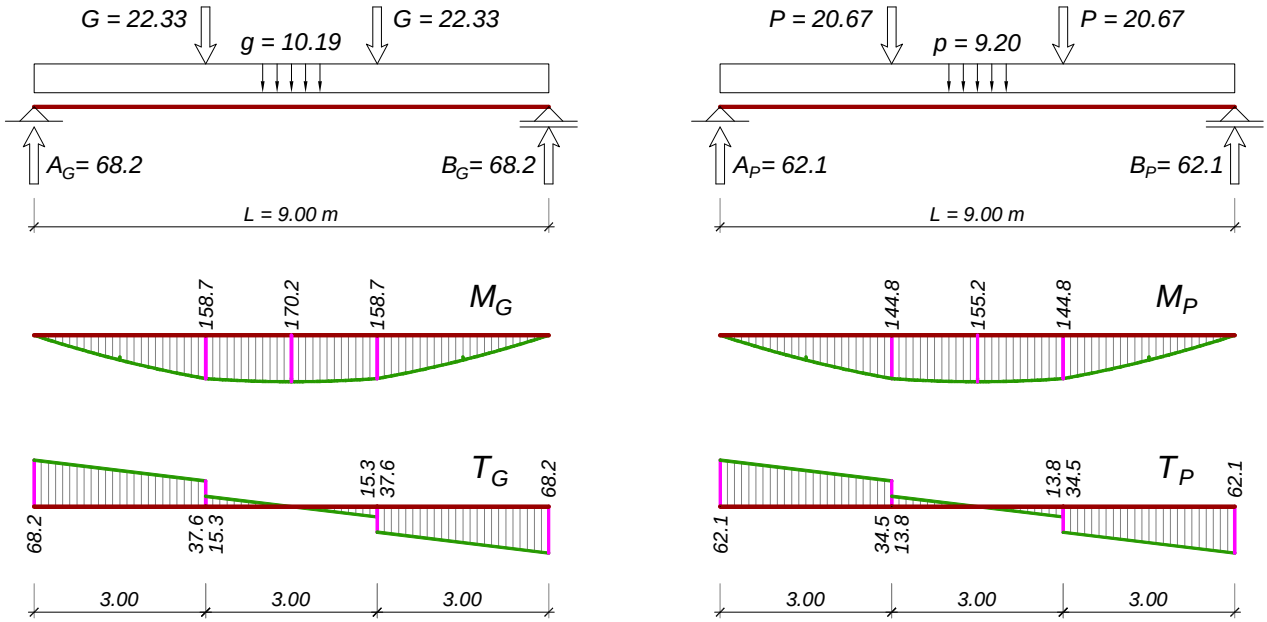
$$EI\delta_{10,P} = EI\delta_{10,P}^{POS2} + EI\delta_{10,P}^{POS3} = 683.1 - 2250.5 = -1567.4 = EI\delta_{20,P}$$

$$X_{1P} = -\frac{-1567.4}{40.44 + 35.39} = 20.67\,kN = X_{2P}$$

Sile koje se prenose na POS 5 (sa POS 2), odnosno POS 4 (sa POS 3):

$$P^{POS2} = 9.20 \times {}^{9.0}\!/_{2} + {}^{2}\!/_{3} \times 20.67 + {}^{1}\!/_{3} \times 20.67 = 62.07\,kN$$
$$P^{POS3} = 9.59 \times {}^{12.0}\!/_{2} + \left(-{}^{2}\!/_{3}\right) \times 20.67 + \left(-{}^{1}\!/_{3}\right) \times 20.67 = 36.87\,kN$$

<u>Dimenzionisanje POS 2</u>



$M_u = 1.6 \times 170.2 + 1.8 \times 155.2 = 551.5\ kNm$

$$B = min.\left\{\begin{matrix} 30 + 0.25 \times 900 = 255 \\ 30 + 20 \times 14 = 310 \end{matrix}\right\} = 255\,cm$$

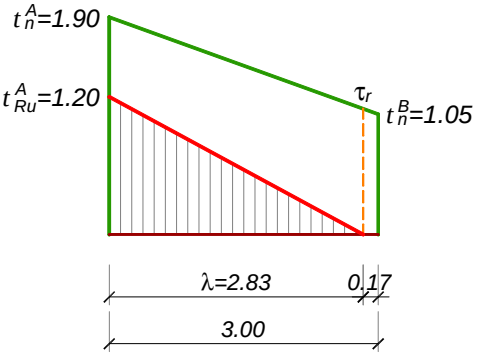
pretp. $a_1 = 7\ cm \quad \Rightarrow \quad h = 50 - 7 = 43\ cm$

$$k = \frac{43}{\sqrt{\frac{551.5 \times 10^2}{255 \times 2.05}}} = 3.211 \quad \Rightarrow \quad \begin{matrix} \varepsilon_b\,/\,\varepsilon_b = 1.892\,/\,10‰ \\ s = 0.159 \Rightarrow x = 0.159 \times 43 = 6.8\,cm < 14\,cm \\ \bar{\mu} = 10.308\% \end{matrix}$$

$$A_a = 10.308 \times \frac{255 \times 43}{100} \times \frac{2.05}{40} = 34.07\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{8RØ25}\ (39.27\ cm^2)$$

$T_u^A = 1.6\times68.2 + 1.8\times62.1 = 220.8\ kN$

$$\tau_n^A = \frac{220.8}{30\times0.9\times43} = 0.190\frac{kN}{cm^2} = 1.90\,MPa \quad \begin{cases} > \tau_r = 1.1\,MPa \\ < 3\tau_r \end{cases}$$



$T_u^B = 1.6\times37.6 + 1.8\times34.5 = 122.2\ kN$

$$\tau_n^B = \frac{122.2}{30\times0.9\times43} = 0.105\frac{kN}{cm^2} = 1.05\,MPa < \tau_r$$

$$\lambda = \frac{1.90-1.1}{1.90-1.05}\times3.0 = 2.83\,m$$

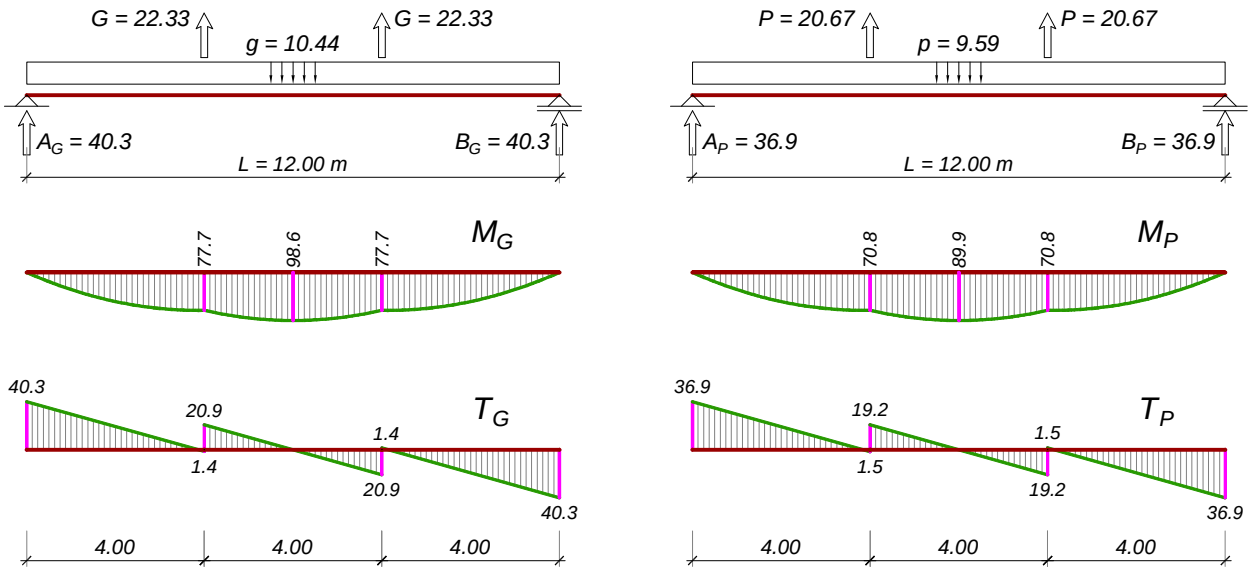
$$\tau_{Ru}^A = \frac{3}{2}\times(0.190-0.11) = 0.12\frac{kN}{cm^2} \quad \Rightarrow \quad e_u = \frac{2\times0.503}{30\times0.120}\times40 = 11.1\,cm$$

usvojeno ***URØ8/10*** *(m=2)*

$$\Delta A_a = \frac{220.8}{2\times40}\times(ctg45^\circ - ctg90^\circ) = 2.76\,cm^2$$

Preko slobodnog oslonca prevodi se minimalno trećina armature iz polja, tj. ***4RØ25****.*

<u>Dimenzionisanje POS 3</u>



$M_u = 1.6\times98.6 + 1.8\times89.9 = 319.7\ kNm$

$$B = min.\begin{Bmatrix} 30+0.25\times1200 = 330 \\ 30+20\times14 = 310 \end{Bmatrix} = 310\,cm \quad ; \quad pretp.\ a_1 = 7\ cm \quad \Rightarrow \quad h = 50 - 7 = 43\ cm$$

$$k = \frac{43}{\sqrt{\frac{319.7\times10^2}{310\times2.05}}} = 4.217 \quad \Rightarrow \quad \begin{array}{l} \varepsilon_b\ /\ \varepsilon_b = 1.301\ /\ 10‰ \\ s = 0.115 \Rightarrow x = 0.115\times43 = 4.95\,cm < 14\,cm \\ \bar{\mu} = 5.863\% \end{array}$$

$$A_a = 5.863\times\frac{310\times43}{100}\times\frac{2.05}{40} = 19.38\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{6RØ22}\ (22.81\ cm^2)$$

$T_{u,max} = 1.6\times40.3 + 1.8\times36.9 = 130.9\ kN$

$$\tau_n = \frac{130.9}{30\times0.9\times43} = 0.113\frac{kN}{cm^2} = 1.13\,MPa \quad \begin{cases} > \tau_r = 1.1\,MPa \\ < 3\tau_r \end{cases}$$

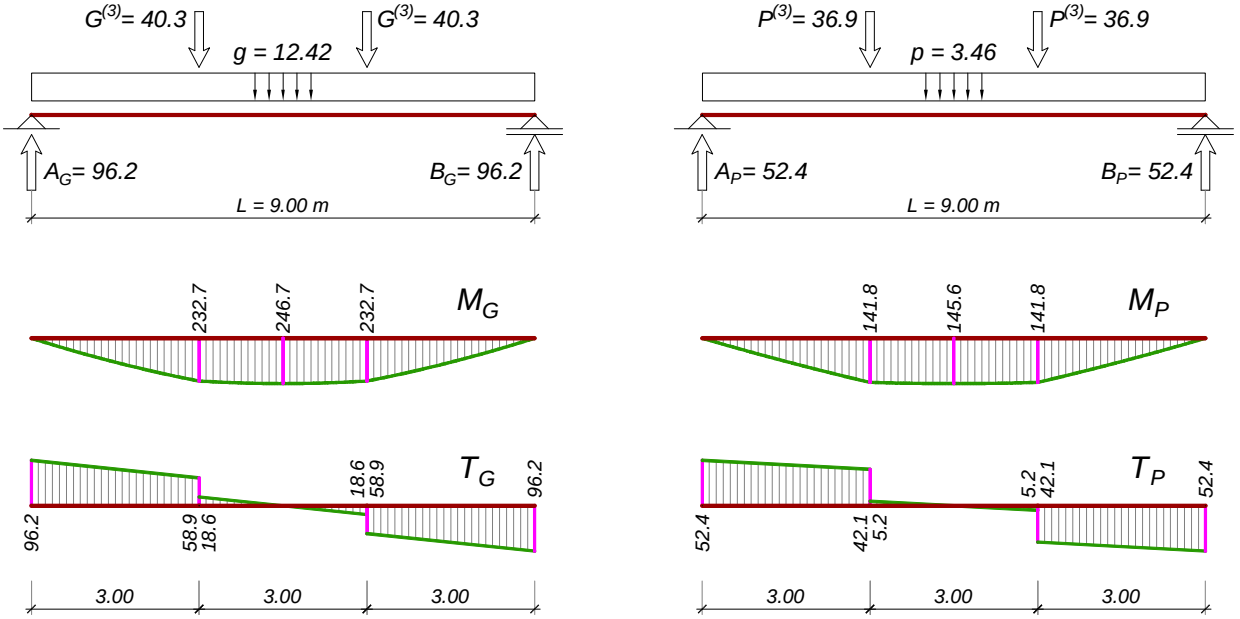
$$\tau_{Ru} = \frac{3}{2}\times(0.113 - 0.11) = 0.04\frac{kN}{cm^2} \quad \Rightarrow \quad e_u = \frac{2\times0.503}{30\times0.2\times10^{-2}} = 16.7\,cm$$

usvojeno ***URØ8/15*** *(m=2) na* $\lambda \approx 1.0\ m$

$$\Delta A_a = \frac{130.9}{2\times40}\times(ctg45° - ctg90°) = 1.64\,cm^2$$

Preko slobodnog oslonca prevodi se minimalno trećina armature iz polja, tj. ***2RØ22****.*

<u>Dimenzionisanje POS 4</u>



$M_u = 1.6\times246.7 + 1.8\times145.6 = 656.9\ kNm$

$$B = min.\begin{Bmatrix} 40 + 0.25\times900/3 = 115 \\ 40 + 8\times14 = 152 \end{Bmatrix} = 115\,cm\ ; \quad pretp.\ a_1 = 7\ cm \quad \Rightarrow \quad h = 100 - 7 = 93\ cm$$

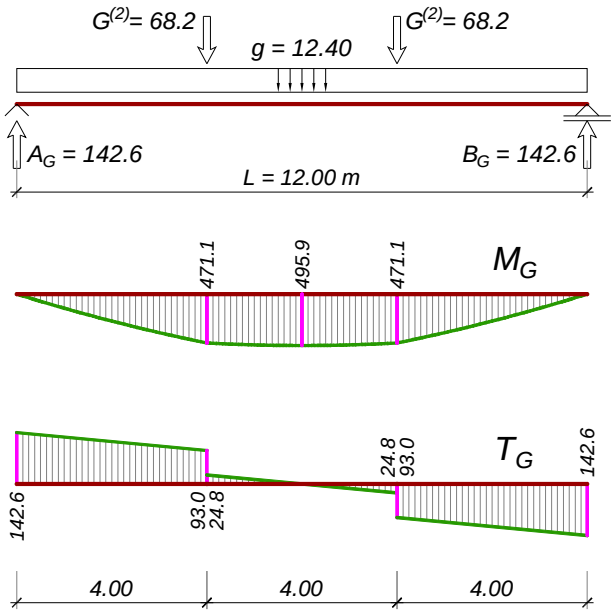
$$k = \frac{93}{\sqrt{\frac{656.9\times10^2}{115\times2.05}}} = 6.363 \quad \Rightarrow \quad \begin{array}{l} \varepsilon_b / \varepsilon_b = 0.794/10‰ \\ s = 0.074 \Rightarrow x = 0.074\times93 = 6.84\,cm < 14\,cm \\ \bar{\mu} = 2.535\% \end{array}$$

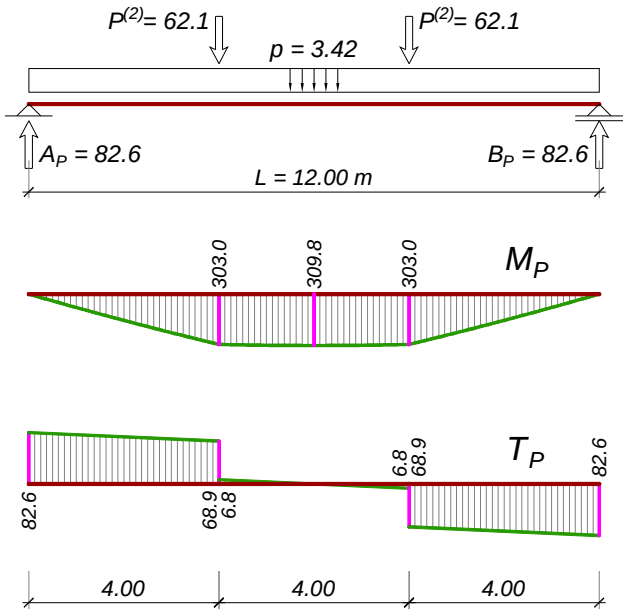
$$A_a = 2.535\times\frac{115\times93}{100}\times\frac{2.05}{40} = 18.12\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{5RØ22}\ (19.00\ cm^2)$$

$T_{u,max} = 1.6\times96.2 + 1.8\times52.4 = 248.3\ kN$

$$\tau_n = \frac{248.3}{40\times0.9\times93} = 0.074\frac{kN}{cm^2} < \tau_r \quad \text{- nije potrebno osiguranje armaturom}$$

Dimenzionisanje POS 5





$M_u = 1.6\times495.9 + 1.8\times309.8 = 1351.2\ kNm$

$$B = min.\begin{Bmatrix} 40+0.25\times1200/3 = 140 \\ 40+8\times14 = 152 \end{Bmatrix} = 140\,cm \quad ; \quad \text{pretp. } a_1 = 7\ cm \quad \Rightarrow \quad h = 100 - 7 = 93\ cm$$

$$k = \frac{93}{\sqrt{\frac{1351.2\times10^2}{140\times2.05}}} = 4.437 \quad \Rightarrow \quad \begin{matrix} \varepsilon_b / \varepsilon_b = 1.22/10‰ \\ s = 0.109 \Rightarrow x = 0.109\times93 = 10.1\,cm < 14\,cm \\ \bar{\mu} = 5.283\% \end{matrix}$$

$$A_a = 5.283\times\frac{140\times93}{100}\times\frac{2.05}{40} = 37.77\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{8RØ25}\ (39.27\ cm^2)$$

$T_{u,max} = 1.6\times142.6 + 1.8\times82.6 = 376.8\ kN$

$$\tau_n = \frac{376.8}{40\times0.9\times93} = 0.113\frac{kN}{cm^2} = 1.13\,MPa \quad \begin{cases} > \tau_r = 1.1\,MPa \\ < 3\tau_r \end{cases}$$

$$\tau_{Ru} = \frac{3}{2}\times(0.113 - 0.11) = 0.04\frac{kN}{cm^2} \quad \Rightarrow \quad e_u = \frac{2\times0.785}{40\times0.2\times10^{-2}} = 19.6\,cm$$

usvojeno **URØ10/15** (m=2) na $\lambda \approx 1.0$ m

$$\Delta A_a = \frac{376.8}{2\times40}\times(ctg45° - ctg90°) = 4.71\,cm^2$$

Preko slobodnog oslonca prevodi se minimalno trećina armature iz polja, tj. ***3RØ25****.*