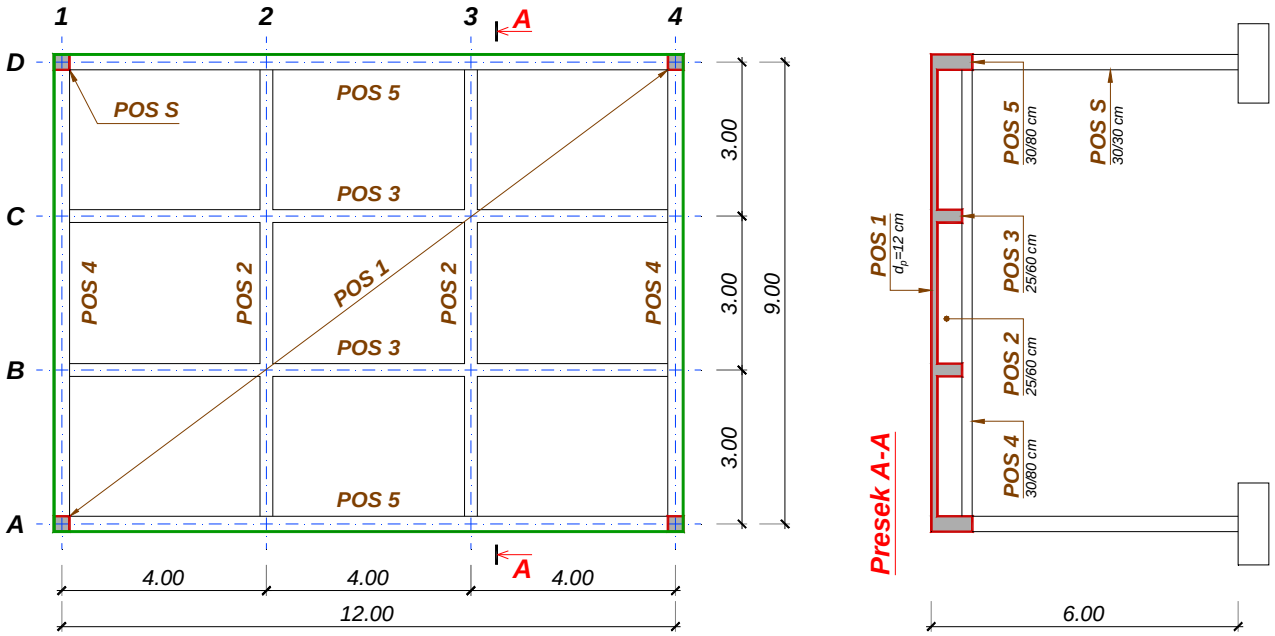
02

Za konstrukciju prikazanu na skici potrebno je:

*1 Dimenzionisati ploču **POS 1** (d_p = 12 cm) u karakterističnim presecima.*

*2 Izvršiti analizu opterećenja, sračunati i nacrtati dijagrame statičkih uticaja za grede **POS 2** i **POS 3** (b/d = 25/60 cm).*



*3 Odrediti potrebnu armaturu greda **POS 2** i **POS 3**. Nacrtati usvojeni raspored armature u poprečnom preseku.*

*4 Izvršiti analizu opterećenja, sračunati i nacrtati dijagrame statičkih uticaja za grede **POS 4** i **POS 5** (b/d = 30/80 cm). Odrediti potrebnu armaturu greda **POS 4** i **POS 5**.*

*Povremeno opterećenje **p = 6.0 kN/m²** deluje po čitavoj površini ploče POS 1. Kvalitet materijala: MB 30, RA 400/500.*

1. POS 1 – ploča d_p = 12 cm

$g = 0.12 \times 25 = 3.0$ kN/m²

$p = 6.0$ kN/m²

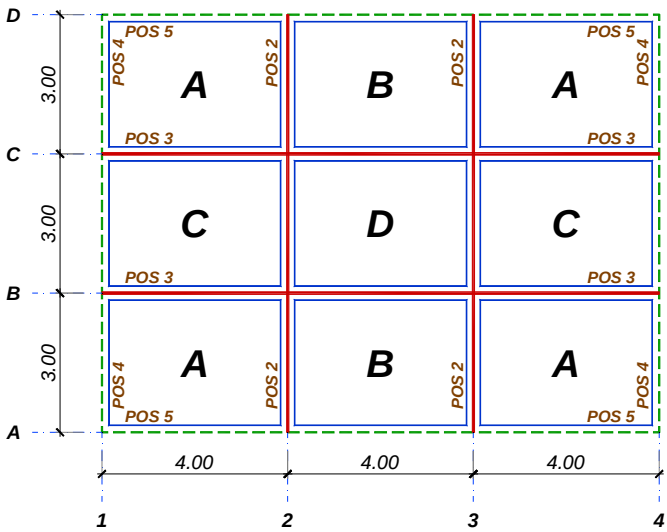
za sve delove ploče:

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

$G = 3.0 \times 4.0 \times 3.0 = 36$ kN

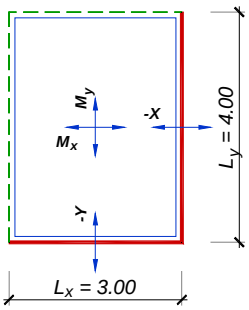
$P = 6.0 \times 4.0 \times 3.0 = 72$ kN

$Q_u = 1.6 \times 36 + 1.8 \times 72 = 187.2$ kN



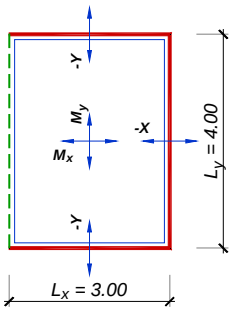
<u>ploča tipa **»A«**</u>

	k		G kNm/m	P kNm/m	U kNm/m
kraći pravac, polje	0.032	M_X	1.15	2.30	**5.99**
duži pravac, polje	0.021	M_Y	0.76	1.51	**3.93**
kraći pravac, oslonac	0.071	-X	2.56	5.11	**13.29**
duži pravac, oslonac	0.059	-Y	2.12	4.25	**11.04**



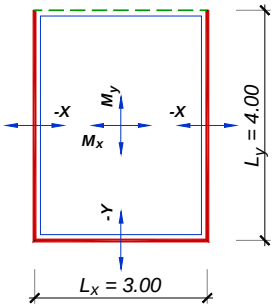
ploča tipa »B«

	k		G kNm/m	P kNm/m	U kNm/m
kraći pravac, polje	0.028	M_X	1.01	2.02	**5.24**
duži pravac, polje	0.022	M_Y	0.79	1.58	**4.12**
kraći pravac, oslonac	0.063	-X	2.27	4.54	**11.79**
duži pravac, oslonac	0.055	-Y	1.98	3.96	**10.30**



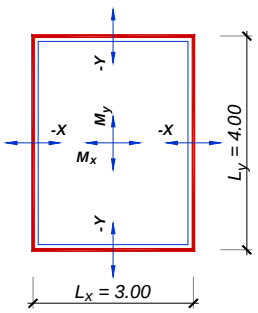
ploča tipa »C«

	k		G kNm/m	P kNm/m	U kNm/m
kraći pravac, polje	0.027	M_X	0.97	1.94	**5.05**
duži pravac, polje	0.014	M_Y	0.50	1.01	**2.62**
kraći pravac, oslonac	0.057	-X	2.05	4.10	**10.67**
duži pravac, oslonac	0.044	-Y	1.58	3.17	**8.24**



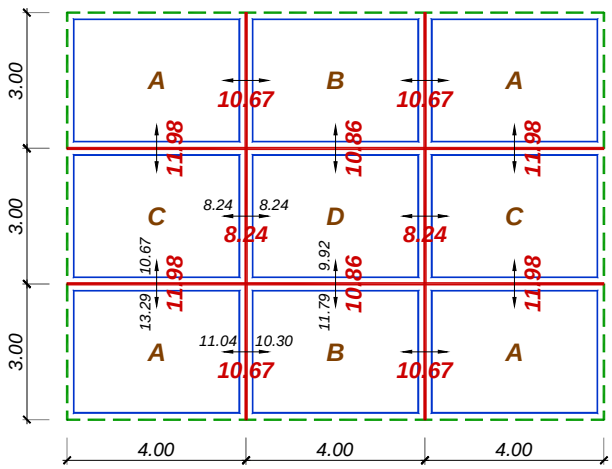
ploča tipa »D«

	k		G kNm/m	P kNm/m	U kNm/m
kraći pravac, polje	0.024	M_X	0.86	1.73	**4.49**
duži pravac, polje	0.015	M_Y	0.54	1.08	**2.81**
kraći pravac, oslonac	0.053	-X	1.91	3.82	**9.92**
duži pravac, oslonac	0.044	-Y	1.58	3.17	**8.24**

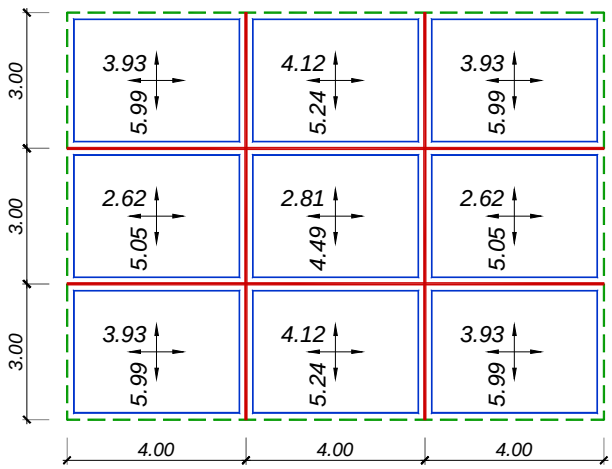


Granični momenti savijanja u ploči, posebno za donju, odnosno gornju zonu su prikazani na donjoj šemi. Vrednosti oslonačkih momenata susednih ploča su osrednjeni na delovima gde se sustiču dve krstaste ploče različitih konturnih uslova.

M_u *[kNm/m] - GORNJA ZONA*



M_u *[kNm/m] - DONJA ZONA*



S obzirom na veličinu momenata savijanja, prvi red armature donje zone biće postavljen u globalnom Y pravcu (max.M_u = 5.99 kNm/m), preko njega donja zona u X pravcu, zatim gornja zona u X pravcu i konačno gornja zona u Y pravcu (max.M_u = 11.98 kNm/m).

Dimenzionisanje

MB 30 $\Rightarrow$ $f_B = 20.5$ *MPa* ; *RA 400/500* $\Rightarrow$ $\sigma_v = 400$ *MPa*

max.M_u = M_{yu} = 11.98 kNm/m *(upravno na POS 3 - oslonac između ploča A i C)*

$a_{1y} = 2.5$ *cm* $\Rightarrow$ $h_y = d - a_{1y} = 12 - 2.5 = 9.5$ *cm*

$$k = \frac{9.5}{\sqrt{\frac{11.98}{2.05}}} = 3.930 \quad \Rightarrow \quad \varepsilon_b/\varepsilon_a = 1.425/10‰ \; ; \; \bar{\mu} = 6.779\%$$

$$A_{aY} = 6.779 \times 9.5 \times \frac{2.05}{40} = 3.30 \text{ cm}^2/\text{m} > A_{a,min.} = 0.1 \times 12 = 1.2 \text{ cm}^2/\text{m}$$

usvojeno: ***RØ8/15*** *(3.35 cm²/m)*

$A_{ap} = 0.2 \times 3.30 = 0.66 \text{ cm}^2/\text{m} < A_{ap,min.} = 0.085 \times 12 = 1.02 \text{ cm}^2/\text{m}$

usvojeno: ***RØ8/30*** *(1.68 cm²/m)*

M_u = 10.86 kNm/m *(upravno na POS 3 - oslonac između ploča B i D)*

$$A_{aY} \approx \frac{10.86}{11.98} \times 3.30 = 2.99 \frac{\text{cm}^2}{\text{m}}$$

usvojeno: ***RØ8/15*** *(3.35 cm²/m)*
RØ8/30 *(1.68 cm²/m) – podeona armatura*

max.M_{xu} = 10.67 kNm/m *(upravno na POS 2 - oslonac između ploča A i B)*

$h_x = 12 - (2.0 + 0.8 + 0.8/2) = 12 - 3.2 = 8.8$ *cm*

$$k = \frac{8.8}{\sqrt{\frac{10.67}{2.05}}} = 3.857 \quad \Rightarrow \quad \varepsilon_b/\varepsilon_a = 1.461/10‰ \; ; \; \bar{\mu} = 7.043\%$$

$$A_{aX} = 7.043 \times 8.8 \times \frac{2.05}{40} = 3.18 \text{ cm}^2/\text{m}$$

usvojeno: ***RØ8/15*** *(3.35 cm²/m)*
RØ8/30 *(1.68 cm²/m) – podeona armatura*

M_u = 8.24 kNm/m *(upravno na POS 2 - oslonac između ploča C i D)*

$$A_{aY} \approx \frac{8.24}{10.67} \times 3.18 = 2.45 \frac{\text{cm}^2}{\text{m}}$$

usvojeno: ***RØ8/20*** *(2.51 cm²/m)*
RØ8/30 *(1.68 cm²/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:

$$RØ8/20 \quad \Rightarrow \quad A_a = \frac{100 \times a_a^{(1)}}{e_a} = \frac{100 \times 0.503}{20} = 2.51 \frac{\text{cm}^2}{\text{m}} > A_{a,\min.} = 0.1 \times 12 = 1.2 \frac{\text{cm}^2}{\text{m}}$$

Nosivost ovako usvojene armature, sračunata sa približnom vrednošću kraka unutrašnjih sila koji odgovara manjoj statičkoj visini $z \approx 0.9 \times 8.8 = 7.92$ cm, je:

$$M_u \approx 2.51 \times 7.92 \times 10^{-2} \times 40 = 7.96 \text{ kNm/m} > M_{u,max} = 5.99 \text{ kNm/m}$$

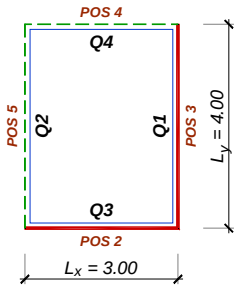
usvojeno: ***RØ8/20*** *(2.51 cm²/m) - donja zona, oba pravca*

2. Analiza opterećenja za grede POS 2 – POS 5

Jednako raspodeljeno opterećenje sa pojedinačnih krstastih ploča:

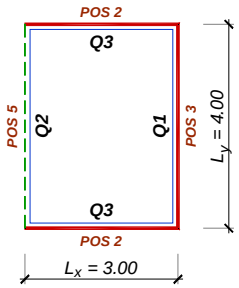
ploča tipa »A«

POS	k		G kN	P kN	L m	g kN/m	p kN/m
3	0.346	Q_1	12.5	24.9	4.0	**3.11**	**6.23**
5	0.233	Q_2	8.4	16.8	4.0	**2.10**	**4.19**
2	0.244	Q_3	8.8	17.6	3.0	**2.93**	**5.86**
4	0.177	Q_4	6.4	12.7	3.0	**2.12**	**4.25**



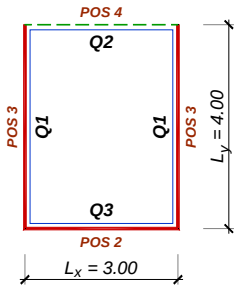
ploča tipa »B«

POS	k		G kN	P kN	L m	g kN/m	p kN/m
3	0.316	Q_1	11.4	22.8	4.0	**2.84**	**5.69**
5	0.218	Q_2	7.8	15.7	4.0	**1.96**	**3.92**
2	0.233	Q_3	8.4	16.8	3.0	**2.80**	**5.59**



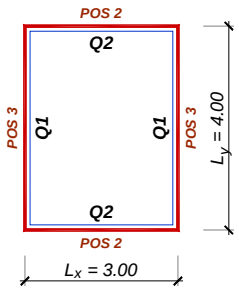
ploča tipa »C«

POS	k		G kN	P kN	L m	g kN/m	p kN/m
3	0.309	Q_1	11.1	22.2	4.0	**2.78**	**5.56**
4	0.165	Q_2	5.9	11.9	3.0	**1.98**	**3.96**
2	0.217	Q_3	7.8	15.6	3.0	**2.60**	**5.21**



ploča tipa »D«

POS	k		G kN	P kN	L m	g kN/m	p kN/m
3	0.291	Q_1	10.5	21.0	4.0	**2.62**	**5.24**
2	0.209	Q_2	7.5	15.0	3.0	**2.51**	**5.02**

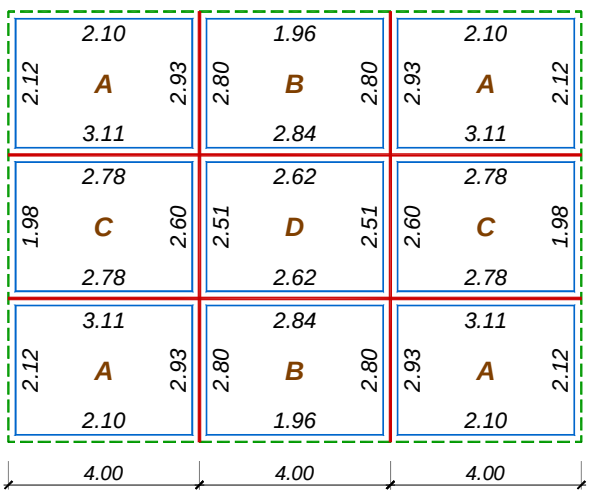


Sopstvenu težinu greda POS 2 i POS 3, odnosno POS 4 i POS 5:

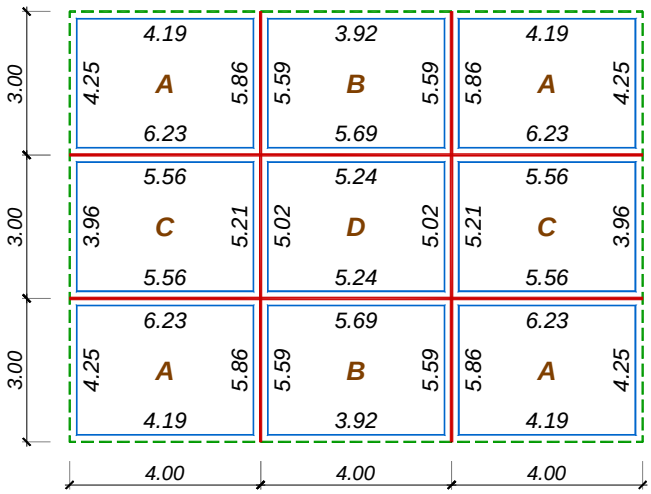
$g_{2,3} = 0.25 \times 0.6 \times 25 = 3.75$ kN/m $g_{4,5} = 0.3 \times 0.8 \times 25 = 6.0$ kN/m

treba dodati prikazanom stalnom opterećenju sa POS 1.

STALNO OPT. g [kN/m]



POVREMENO OPT. p [kN/m]



grede POS 2:

$g_1 = 2.93 + 2.80 + 3.75 = 9.47\ kN/m = g_3$; $p_1 = 5.86 + 5.59 = 11.45\ kN/m = p_3$

$g_2 = 2.60 + 2.51 + 3.75 = 8.86\ kN/m$; $p_2 = 5.21 + 5.02 = 10.22\ kN/m$

grede POS 3:

$g_1 = 3.11 + 2.78 + 3.75 = 9.65\ kN/m = g_3$; $p_1 = 6.23 + 5.56 = 11.79\ kN/m = p_3$

$g_2 = 2.84 + 2.62 + 3.75 = 9.21\ kN/m$; $p_2 = 5.69 + 5.24 = 10.93\ kN/m$

grede POS 4:

$g_1 = 2.12 + 6.0 = 8.12\ kN/m = g_3$; $p_1 = 4.25\ kN/m = p_3$

$g_2 = 1.98 + 6.0 = 7.98\ kN/m$; $p_2 = 3.96\ kN/m$

grede POS 5:

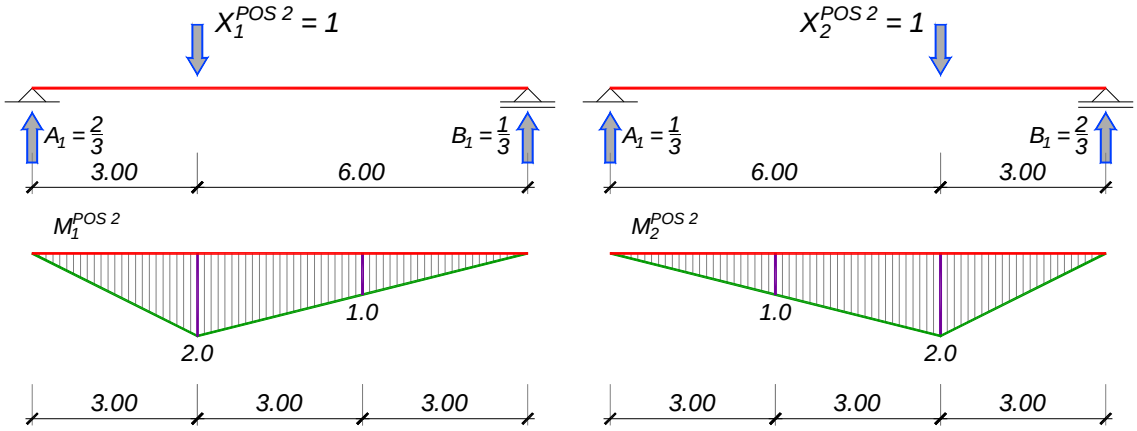
$g_1 = 2.10 + 6.0 = 8.10\ kN/m = g_3$; $p_1 = 4.19\ kN/m = p_3$

$g_2 = 1.96 + 6.0 = 7.96\ kN/m$; $p_2 = 3.92\ kN/m$

Kod procene 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=25/60 cm) su daleko manje krutosti od greda POS 4 i POS 5 (b/d=30/80 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 30/30 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 usled stalnog (G) i povremenog (P) opterećenja.



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

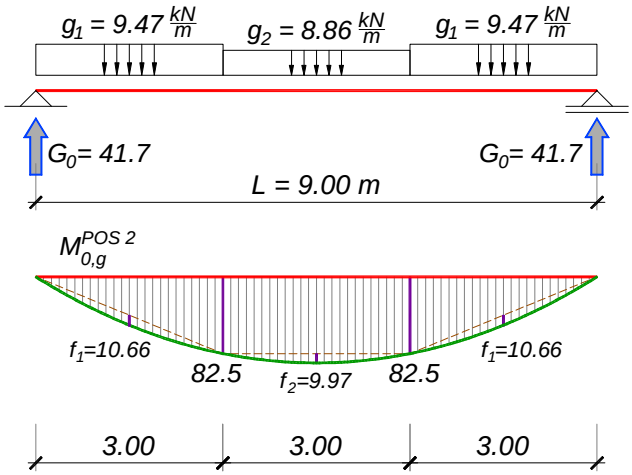
$$EI\delta_{12}^{POS\,2} = 2\times\frac{3.0}{3}\times 2.0\times 1.0+\frac{3.0}{6}\times\left[2.0\times(2\times 1.0+2.0)+1.0\times(2\times 2.0+1.0)\right]=10.5=EI\delta_{21}^{POS\,2}$$

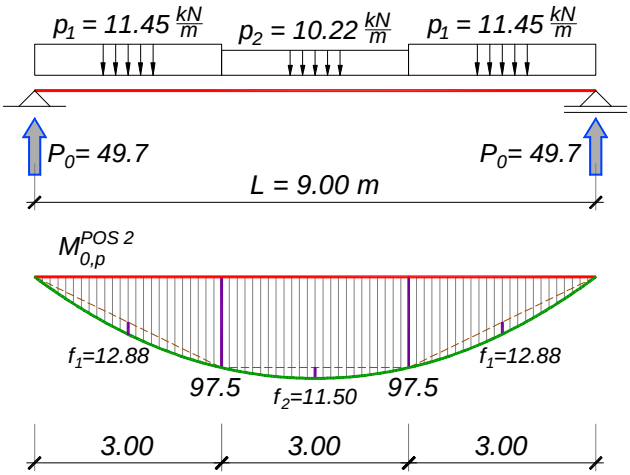
$$G_0=\frac{2\times 9.47+8.86}{2}\times 3.0=41.7\,kN \quad ; \quad P_0=\frac{2\times 11.45+10.22}{2}\times 3.0=49.7\,kN$$

$M_{0g} = 41.7\times 3.0 - 9.47\times 3.0^2/2 = 82.5\ kNm$; $M_{0p} = 49.7\times 3.0 - 11.45\times 3.0^2/2 = 97.5\ kNm$

$f_{1g} = 9.47\times 3.0^2/8 = 10.66\ kNm$; $f_{1p} = 11.45\times 3.0^2/8 = 12.88\ kNm$

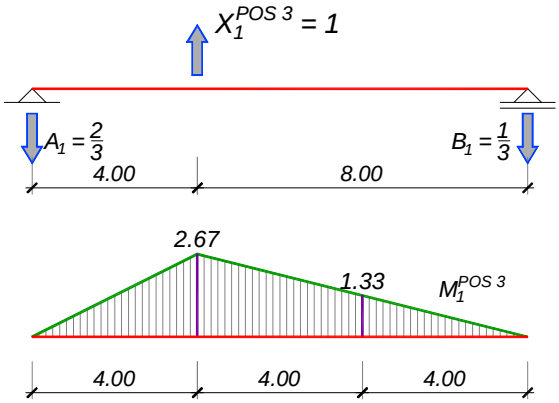
$f_{2g} = 8.86\times 3.0^2/8 = 9.97\ kNm$; $f_{2p} = 10.22\times 3.0^2/8 = 11.50\ kNm$

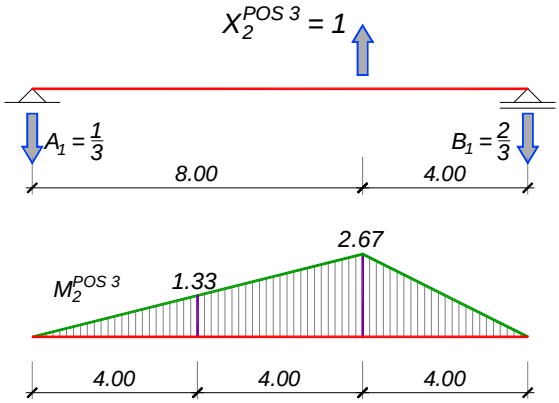




$$EI\delta_{10,g}^{POS\,2} = \frac{3.0}{3}\times(82.5\times 2.0+82.5\times 1.0)+\frac{3.0}{3}\times 10.66\times(1.0+2.0)+\frac{3.0}{2}\times 82.5\times(2.0+1.0)+$$
$$+\frac{3.0}{3}\times 9.97\times(2.0+1.0)=680.7=EI\delta_{20,g}^{POS\,2}$$

$$EI\delta_{10,p}^{POS\,2} = \frac{3.0}{3}\times(97.5\times 2.0+97.5\times 1.0)+\frac{3.0}{3}\times 12.88\times(1.0+2.0)+\frac{3.0}{2}\times 97.5\times(2.0+1.0)+$$
$$+\frac{3.0}{3}\times 11.50\times(2.0+1.0)=804.6=EI\delta_{20,p}^{POS\,2}$$





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

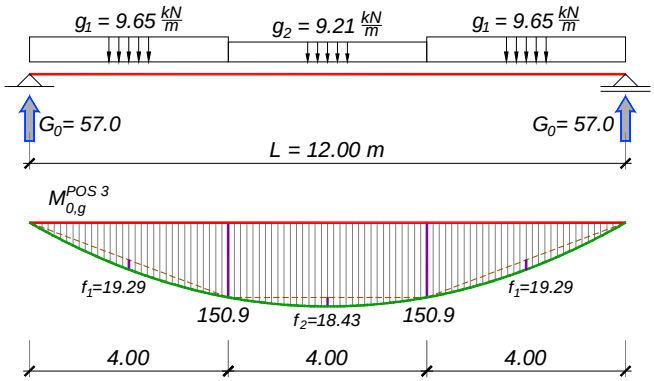
$$EI\delta_{12}^{POS\,3} = 2\times\frac{4.0}{3}\times 2.67\times 1.33+\frac{4.0}{6}\times\left[2.67\times(2\times 1.33+2.67)+1.33\times(2\times 2.67+1.33)\right]=24.89$$

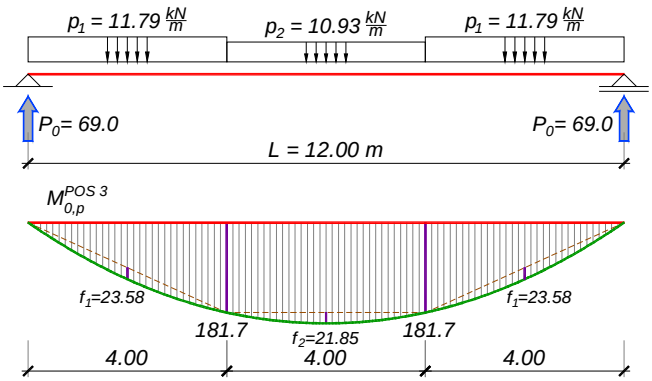
$$G_0=\frac{2\times 9.65+9.21}{2}\times 4.0=57.0\,kN \quad ; \quad P_0=\frac{2\times 11.79+10.93}{2}\times 4.0=69.0\,kN$$

$M_{0g} = 57\times4.0 - 9.65\times4.0^2/2 = 150.9\ kNm$; $M_{0p} = 69\times4.0 - 11.79\times4.0^2/2 = 181.7\ kNm$

$f_{1g} = 9.65\times4.0^2/8 = 19.29\ kNm$; $f_{1p} = 11.79\times4.0^2/8 = 23.58\ kNm$

$f_{2g} = 9.21\times4.0^2/8 = 18.43\ kNm$; $f_{2p} = 10.93\times4.0^2/8 = 21.85\ kNm$





$$-EI\delta_{10,g}^{POS3} = \frac{4.0}{3}\times(150.9\times2.67+150.9\times1.33)+\frac{4.0}{3}\times19.29\times(1.33+2.67)+$$
$$+\frac{4.0}{2}\times150.9\times(2.67+1.33)+\frac{4.0}{3}\times18.43\times(2.67+1.33)=2212.7=-EI\delta_{20,g}^{POS3}$$

$$-EI\delta_{10,p}^{POS3} = \frac{4.0}{3}\times(181.7\times2.67+181.7\times1.33)+\frac{4.0}{3}\times23.58\times(1.33+2.67)+$$
$$+\frac{4.0}{2}\times181.7\times(2.67+1.33)+\frac{4.0}{3}\times21.85\times(2.67+1.33)=2665.3=-EI\delta_{20,p}^{POS3}$$

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

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

<u>*a. stalno opterećenje*</u>

$$EI\delta_{10,g}=EI\delta_{10,g}^{POS2}+EI\delta_{10,g}^{POS3}=680.7-2212.7=-1531.9=EI\delta_{20,g}$$

$$\left.\begin{aligned}EI\delta_{11}\cdot X_{1g}+EI\delta_{12}\cdot X_{2g}+EI\delta_{10,g}=0\\EI\delta_{21}\cdot X_{1g}+EI\delta_{22}\cdot X_{2g}+EI\delta_{20,g}=0\end{aligned}\right\}\Rightarrow X_{1g}=-\frac{-1531.9}{40.44+35.39}=20.2\,kN=X_{2g}$$

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

$$G^{POS2}=41.7+\tfrac{2}{3}\times20.2+\tfrac{1}{3}\times20.2=61.9\,kN$$
$$G^{POS3}=57.0+\left(-\tfrac{2}{3}\right)\times20.2+\left(-\tfrac{1}{3}\right)\times20.2=36.8\,kN$$

<u>*b. povremeno opterećenje*</u>

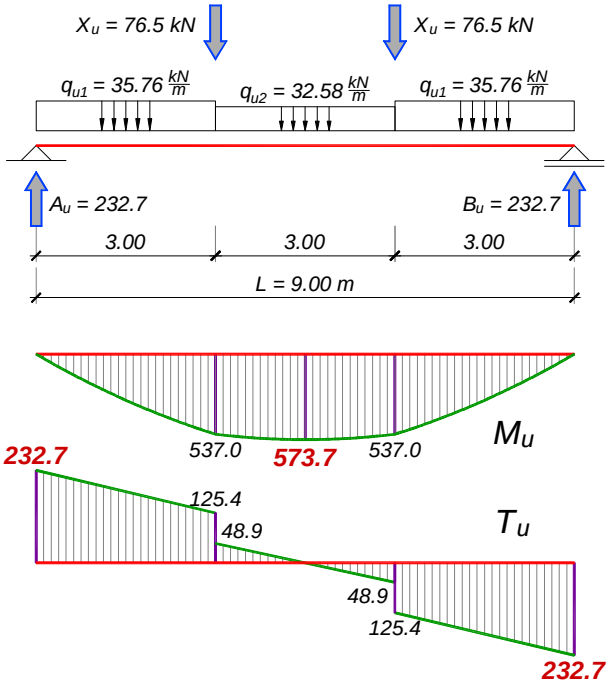
$$EI\delta_{10,p}=EI\delta_{10,p}^{POS2}+EI\delta_{10,p}^{POS3}=804.6-2665.3=-1860.8=EI\delta_{20,p}$$

$$X_{1p}=-\frac{-1860.8}{40.44+35.39}=24.5\,kN=X_{2p}$$

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

$$P^{POS2}=49.7+\tfrac{2}{3}\times24.5+\tfrac{1}{3}\times24.5=74.2\,kN$$
$$P^{POS3}=69.0+\left(-\tfrac{2}{3}\right)\times24.5+\left(-\tfrac{1}{3}\right)\times24.5=44.5\,kN$$

3. Dimenzionisanje POS 2 i POS 3



Dimenzionisanje POS 2

$q_{u1} = 1.6\times9.47+1.8\times11.45 = 35.76\ kN/m$

$q_{u2} = 1.6\times8.86+1.8\times10.22 = 32.58\ kN/m$

$X_u = 1.6\times20.2 + 1.8\times24.5 = 76.5\ kN$

$$A_u = \frac{2\times35.76+32.58}{2}\times3.0+76.5 = 232.7\ kN$$

$$T_u^{B,l} = 232.7-35.76\times3.0 = 125.4\ kN$$

$$T_u^{B,d} = 125.4-76.5 = 48.9\ kN$$

$$M_u^B = 232.7\times3.0-\frac{35.76\times3.0^2}{2} = 537.0\ kNm$$

$$M_{u,\max} = 537+48.9\times\frac{3}{2}-\frac{32.58\times3^2}{8} = 573.7\ kNm$$

$$B = \min.\begin{Bmatrix}25+0.25\times900 = 250\\ 25+20\times12 = 265\end{Bmatrix} = 250\ cm$$

pretp. $a_1 = 7\ cm \Rightarrow h = 60-7 = 53\ cm$

$$k = \frac{53}{\sqrt{\frac{573.7\times10^2}{250\times2.05}}} = 5.009 \Rightarrow \begin{array}{l}\varepsilon_b/\varepsilon_a = 1.051/10‰\\ s = 0.095 \Rightarrow x = 0.095\times53 = 5.0\ cm < 12\ cm\\ \bar{\mu} = 4.123\%\end{array}$$

$$A_a = 4.123\times\frac{250\times53}{100}\times\frac{2.05}{40} = 28.00\ cm^2 \Rightarrow$$ usvojeno **6RØ25** ($29.45\ cm^2$)

$$\tau_n^A = \frac{232.7}{25\times0.9\times53} = 0.195\ \frac{kN}{cm^2}\begin{cases}>\tau_r = 1.1\ MPa\\ <3\tau_r\end{cases}$$

$$\tau_n^{B,l} = \frac{125.4}{25\times0.9\times53} = 0.105\ \frac{kN}{cm^2} = 1.05\ MPa < \tau_r$$

$$\lambda = \frac{1.95-1.1}{1.95-1.05}\times3.0 = 2.838\ m$$

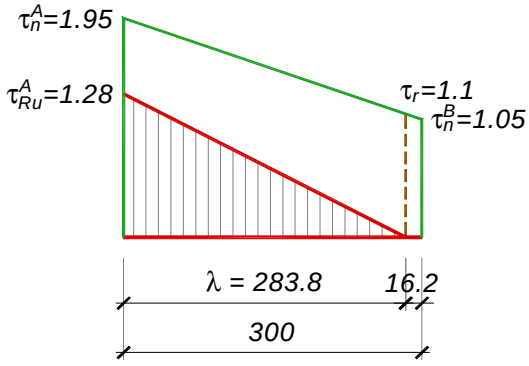
$$\tau_{Ru}^A = \frac{3}{2}\times(0.195-0.11) = 0.128\ \frac{kN}{cm^2}$$

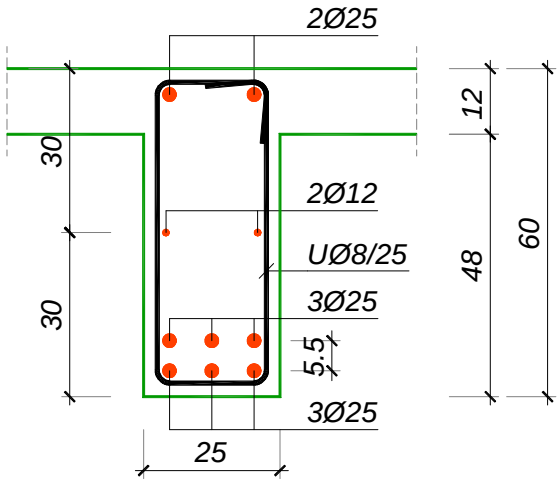
$$e_u = \frac{2\times0.503}{25\times0.128}\times40 = 12.6\ cm$$

usvojeno **URØ8/12.5** (m=2)

$$\Delta A_a = \frac{232.7}{2\times40}\times(\cot45°-\cot90°) = 2.91\ cm^2$$

Preko slobodnog oslonca prevodi se minimalno trećina armature iz polja, tj. ***2RØ25****.*





Dimenzionisanje POS 3

$q_{u1} = 1.6\times9.65+1.8\times11.79 = 36.65\ kN/m$

$q_{u2} = 1.6\times9.21+1.8\times10.93 = 34.41\ kN/m$

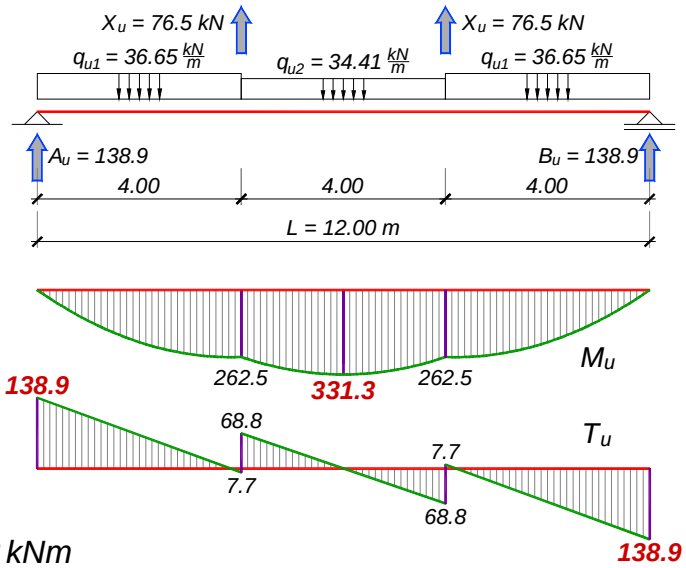
$X_u = 1.6\times20.2 + 1.8\times24.5 = 76.5\ kN$

$$A_u = \frac{2\times36.65+34.41}{2}\times4-76.5 = 138.9\,kN$$

$$T_u^{B,l} = 138.9-36.65\times4.0 = -7.7\,kN$$

$$T_u^{B,d} = -7.7-(-76.5) = 68.8\,kN$$

$$M_u^B = 138.9\times4-\frac{36.65\times4^2}{2} = 262.5\,kNm$$



$$M_{u,max} = 262.5+68.8\times\frac{4}{2}-\frac{34.41\times4^2}{8} = 331.3\,kNm$$

$$B = \min.\begin{Bmatrix}25+0.25\times1200 = 325\\ 25+20\times12 = 265\end{Bmatrix} = 265\,cm \quad ; \quad \text{pretp. } a_1 = 6\ cm \quad \Rightarrow \quad h = 60-6 = 54\ cm$$

$$k = \frac{54}{\sqrt{\frac{331.3\times10^2}{265\times2.05}}} = 6.914 \quad \Rightarrow \quad \varepsilon_b/\varepsilon_a = 0.723/10‰$$

$$s = 0.067 \Rightarrow x = 0.067\times54 = 3.6\,cm < 12\,cm$$

$$\bar{\mu} = 2.141\%$$

$$A_a = 2.141\times\frac{265\times54}{100}\times\frac{2.05}{40} = 15.71\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{5RØ22}\ (19.01\ cm^2)$$

$$\tau_n^A = \frac{138.9}{25\times0.9\times54} = 0.114\,\frac{kN}{cm^2} > \tau_r$$

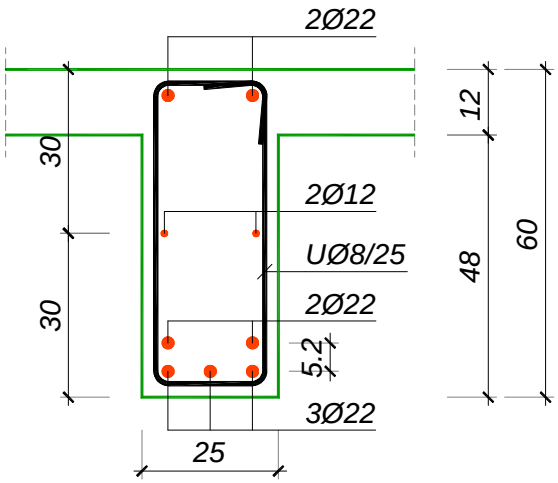
$$\tau_{Ru}^A = \frac{3}{2}\times(0.114-0.11) = 0.007\,\frac{kN}{cm^2}$$

$$e_u \le \frac{m\times a_u^{(1)}}{b\times\mu_{uz,min}} = \frac{2\times0.503}{25\times0.2\%} = 20.1\,cm$$

usvojeno **URØ8/20** *(m=2)*

$$\Delta A_a = \frac{138.9}{2\times40}\times(\cot45°-\cot90°) = 1.74\,cm^2$$

usvojeno **2RØ22** *(7.60 cm²)*



4. Proračun statičkih uticaja i dimenzionisanje POS 4 i POS 5

Proračun POS 4

$q_{u1} = 1.6\times8.12+1.8\times4.25 = 20.64\ kN/m$; $q_{u2} = 1.6\times7.98+1.8\times3.96 = 19.90\ kN/m$

$Q_u = 1.6\times36.8 + 1.8\times44.5 = 138.9\ kN$

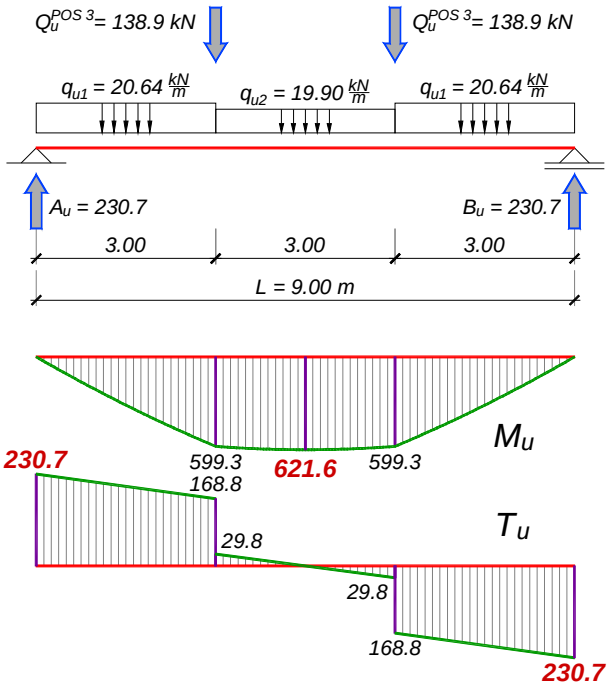
$$A_u = \frac{2\times20.64+19.90}{2}\times3.0+138.9 = 230.7\,kN$$

$$T_u^{B,l} = 230.7-20.64\times3.0 = 168.8\,kN \quad ; \quad T_u^{B,d} = 168.8-138.9 = 29.8\,kN$$

$$M_u^B = 230.7 \times 3.0 - \frac{20.64 \times 3.0^2}{2} = 599.3\,kNm$$

$$M_{u,max} = 599.3 + 29.8 \times \frac{3}{2} - \frac{19.90 \times 3^2}{8} = 621.6\,kNm$$

$$B = \min.\begin{Bmatrix} 30 + 0.25 \times 900/3 = 105 \\ 30 + 8 \times 12 = 126 \end{Bmatrix} = 105\,cm$$



pretp. $a_1 = 7\,cm \quad \Rightarrow \quad h = 80 - 7 = 73\,cm$

$$k = \frac{73}{\sqrt{\frac{621.6 \times 10^2}{105 \times 2.05}}} = 4.296$$

$$\varepsilon_b / \varepsilon_a = 1.271/10‰$$

$$s = 0.113 \Rightarrow x = 0.113 \times 73 = 8.2\,cm < 12\,cm$$

$$\bar{\mu} = 5.646\%$$

$$A_a = 5.646 \times \frac{105 \times 73}{100} \times \frac{2.05}{40} = 22.18\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{6RØ22}\ (22.81\,cm^2)$$

$$\tau_n^A = \frac{230.7}{30 \times 0.9 \times 73} = 0.117\,\frac{kN}{cm^2} > \tau_r$$

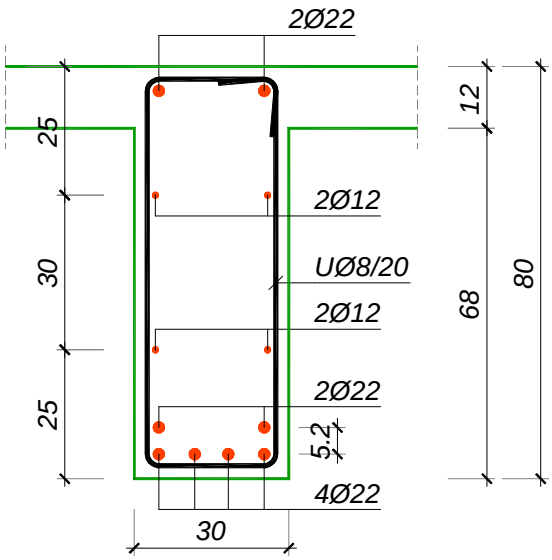
$$\tau_{Ru}^A = \frac{3}{2} \times (0.117 - 0.11) = 0.011\,\frac{kN}{cm^2}$$

$$e_u \le \frac{m \times a_u^{(1)}}{b \times \mu_{uz,min}} = \frac{2 \times 0.503}{30 \times 0.2\%} = 16.8\,cm$$

usvojeno **URØ8/15** *(m=2)*

$$\Delta A_a = \frac{230.7}{2 \times 40} \times (\cot 45° - \cot 90°) = 2.88\,cm^2$$

usvojeno **2RØ22** *(7.60 cm²)*



Proračun POS 5

$q_{u1} = 1.6 \times 8.10 + 1.8 \times 4.19 = 20.50\,kN/m$; $q_{u2} = 1.6 \times 7.96 + 1.8 \times 3.92 = 19.80\,kN/m$

$Q_u = 1.6 \times 61.9 + 1.8 \times 74.2 = 232.7\,kN$

$$A_u = \frac{2 \times 20.50 + 19.80}{2} \times 4.0 + 232.7 = 354.3\,kN$$

$$T_u^{B,l} = 354.3 - 20.50 \times 4.0 = 272.3\,kN \quad ; \quad T_u^{B,d} = 272.3 - 232.7 = 39.6\,kN$$

$$M_u^B = 354.3 \times 4.0 - \frac{20.50 \times 4.0^2}{2} = 1253.1\,kNm$$

$$M_{u,max} = 1253.1 + 39.6 \times \frac{4.0}{2} - \frac{19.80 \times 4.0^2}{8} = 1292.7\,kNm$$

$$B = \min.\begin{Bmatrix} 30 + 0.25 \times 1200/3 = 130 \\ 30 + 8 \times 12 = 126 \end{Bmatrix} = 126\,cm$$

pretp. $a_1 = 9\ cm \Rightarrow h = 80 - 9 = 71\ cm$

$$k = \frac{71}{\sqrt{\frac{1292.7 \times 10^2}{126 \times 2.05}}} = 3.174$$

$$\varepsilon_b / \varepsilon_a = 1.927 / 10‰$$

$$s = 0.162 \Rightarrow x = 0.162 \times 71 = 11.5\ cm < 12\ cm$$

$$\bar{\mu} = 10.564\%$$

$$A_a = 10.564 \times \frac{126 \times 71}{100} \times \frac{2.05}{40} = 48.43\ cm^2$$

usvojeno ***10RØ25*** *(49.09 cm²)*

$$\tau_n^A = \frac{354.3}{30 \times 0.9 \times 73} = 0.185\ \frac{kN}{cm^2} \begin{cases} > \tau_r \\ < 3\tau_r \end{cases}$$

$$\tau_n^{B,l} = \frac{272.3}{30 \times 0.9 \times 73} = 0.142\ \frac{kN}{cm^2} > \tau_r$$

Dužina osiguranja $\lambda = 4.0$ *m.*

$$\tau_{Ru}^A = \frac{3}{2} \times (0.185 - 0.11) = 0.112\ \frac{kN}{cm^2}$$

$$e_u = \frac{2 \times 0.503}{30 \times 0.112} \times 40 = 11.9\ cm$$

usvojeno ***URØ8/10*** *(m=2)*

$$\Delta A_a = \frac{354.3}{2 \times 40} \times (\cot 45° - \cot 90°) = 4.43\ cm^2$$

usvojeno ***4RØ25*** *(19.63 cm²)*