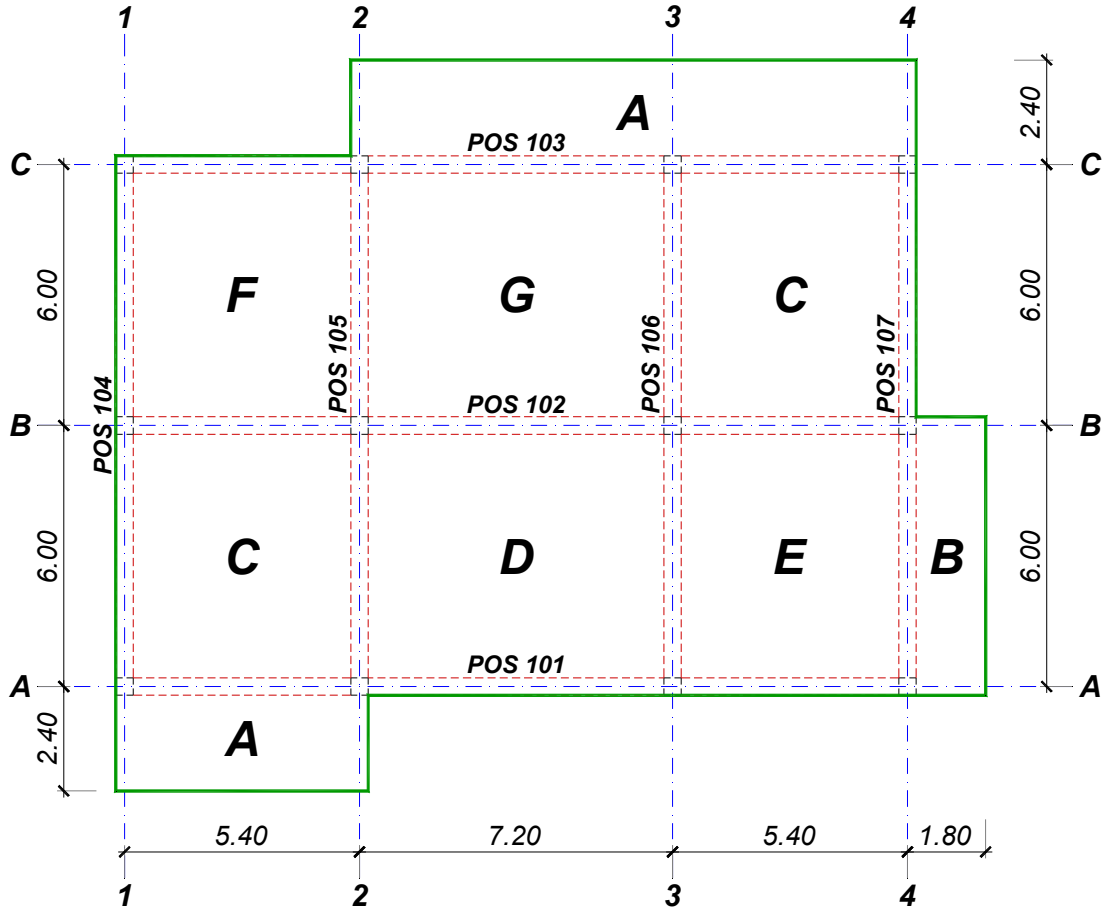
PRORAČUN KRSTASTO ARMIRANE PLOČE



Procena debljine ploče

$$d_{p,min.} = \frac{L_0}{35} \approx \frac{0.8 \times 600}{35} = \frac{2 \times 240}{35} = 13.7 \text{ cm} \Rightarrow \text{usvojeno } d_p = 16 \text{ cm}$$

Analiza opterećenja

sopstvena težina ploče	0.16×25		= 4.0 kN/m^2
dodatno stalno opterećenje			= 2.0 kN/m^2
ukupno, stalno opterećenje		g	= 6.0 kN/m^2
povremeno opterećenje		p	= 10.0 kN/m^2

Ploča "A"

Konzolna ploča, raspona L=2.4 m.

$M_G = 6.0 \times 2.4^2/2 = 17.3$ kNm/m $\quad M_P = 10.0 \times 2.4^2/2 = 28.8$ kNm/m

$M_u = 1.6 \times 17.3 + 1.8 \times 28.8 = 79.5$ kNm/m

Ploča "B"

Konzolna ploča, raspona L=1.8 m.

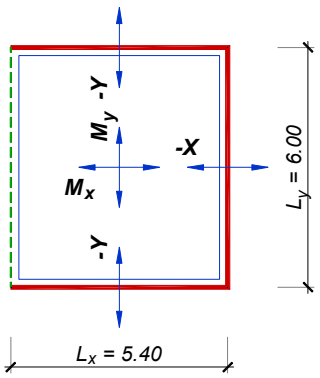
$M_G = 6.0 \times 1.8^2/2 = 9.7$ kNm/m $\quad M_P = 10.0 \times 1.8^2/2 = 16.2$ kNm/m

$M_u = 1.6 \times 9.7 + 1.8 \times 16.2 = 44.7$ kNm/m

Ploča "C"

$L_y / L_x = 6.0/5.4 = 1.11 \approx 1.1$
$G = g \times L_x \times L_y = 6.0 \times 5.4 \times 6.0 = 194.4$ kN
$P = p \times L_x \times L_y = 10.0 \times 5.4 \times 6.0 = 324.0$ kN

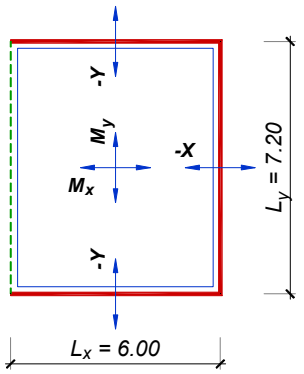
	k		G kNm/m	P kNm/m	U kNm/m
kraći pravac, polje	0.024	M_X	4.7	7.8	**21.5**
duži pravac, polje	0.025	M_Y	4.9	8.1	**22.4**
kraći pravac, oslonac	0.059	-X	11.5	19.1	**52.8**
duži pravac, oslonac	0.059	-Y	11.5	19.1	**52.8**



Ploča "D"

$L_y / L_x = 7.2/6.0 = 1.20$
$G = g \times L_x \times L_y = 6.0 \times 6.0 \times 7.2 = 259.2$ kN
$P = p \times L_x \times L_y = 10.0 \times 6.0 \times 7.2 = 432.0$ kN

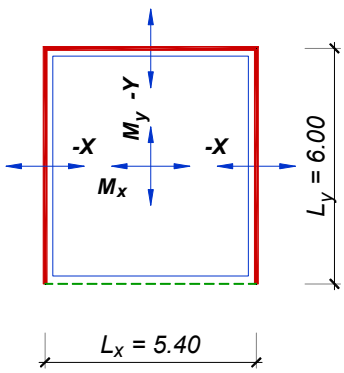
	k		G kNm/m	P kNm/m	U kNm/m
kraći pravac, polje	0.026	M_X	6.7	11.2	**31.0**
duži pravac, polje	0.023	M_Y	6.0	9.9	**27.4**
kraći pravac, oslonac	0.062	-X	16.1	26.8	**73.9**
duži pravac, oslonac	0.058	-Y	15.0	25.1	**69.2**



Ploča "E"

$L_y / L_x = 6.0/5.4 = 1.11 \approx 1.1$
$G = g \times L_x \times L_y = 6.0 \times 5.4 \times 6.0 = 194.4$ kN
$P = p \times L_x \times L_y = 10.0 \times 5.4 \times 6.0 = 324.0$ kN

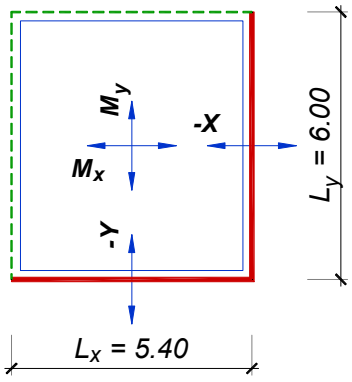
	k		G kNm/m	P kNm/m	U kNm/m
kraći pravac, polje	0.026	M_X	5.1	8.4	**23.3**
duži pravac, polje	0.018	M_Y	3.5	5.8	**16.1**
kraći pravac, oslonac	0.060	-X	11.7	19.4	**53.7**
duži pravac, oslonac	0.052	-Y	10.1	16.8	**46.5**



Ploča "F"

$L_y / L_x = 6.0/5.4 = 1.11 \approx 1.1$
$G = g \times L_x \times L_y = 6.0 \times 5.4 \times 6.0 = 194.4$ kN
$P = p \times L_x \times L_y = 10.0 \times 5.4 \times 6.0 = 324.0$ kN

	k		G kNm/m	P kNm/m	U kNm/m
kraći pravac, polje	0.030	M_X	5.8	9.7	**26.8**
duži pravac, polje	0.025	M_Y	4.9	8.1	**22.4**
kraći pravac, oslonac	0.070	-X	13.6	22.7	**62.6**
duži pravac, oslonac	0.065	-Y	12.6	21.1	**58.1**



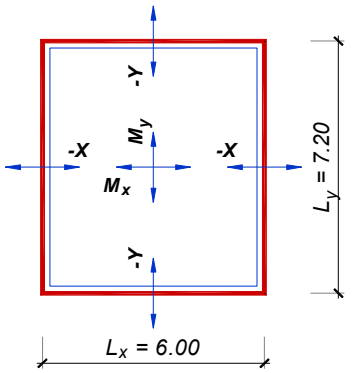
Ploča "G"

$L_y / L_x = 7.2/6.0 = 1.20$

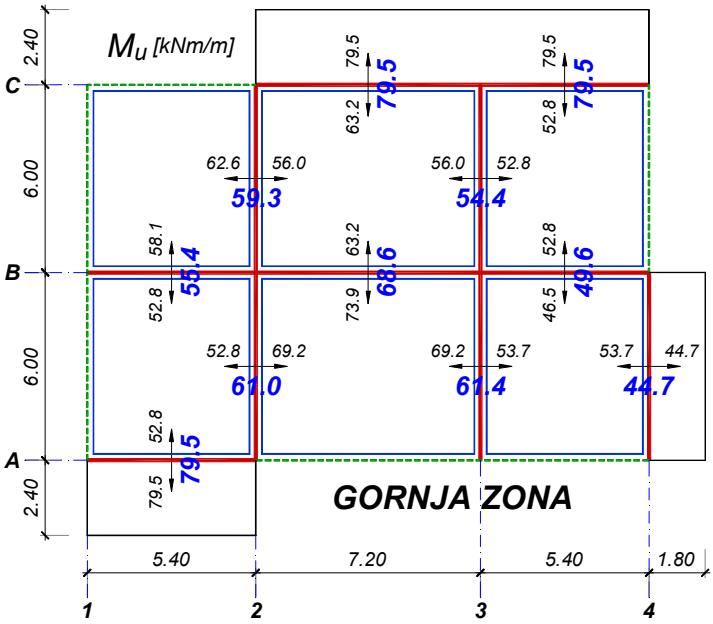
$G = g \times L_x \times L_y = 6.0 \times 6.0 \times 7.2 = 259.2$ kN

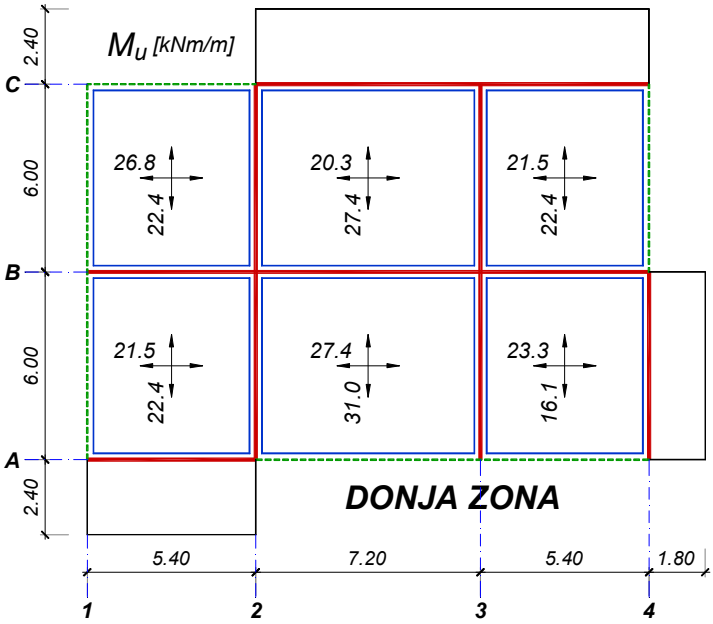
$P = p \times L_x \times L_y = 10.0 \times 6.0 \times 7.2 = 432.0$ kN

	k		G kNm/m	P kNm/m	U kNm/m
kraći pravac, polje	0.023	M_X	6.0	9.9	**27.4**
duži pravac, polje	0.017	M_Y	4.4	7.3	**20.3**
kraći pravac, oslonac	0.053	-X	13.7	22.9	**63.2**
duži pravac, oslonac	0.047	-Y	12.2	20.3	**56.0**



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 i/ili dimenzija. Na delovima gde se krstasta ploča sustiče sa konzolnim prepustom (ploče »A« i »B«), zadržane su vrednosti momenata savijanja sa konzola.





Kako su momenti u globalnom Y pravcu veći od momenata u X pravcu, šipke Y pravca se postavljaju u prvi, odnosno četvrti red, a šipke X pravca u drugi, odnosno treći red (sa manjom statičkom visinom i u gornjoj i u donjoj zoni).

Dimenzionisanje - gornja zona

usvojeno: MB 30 $\Rightarrow$ f_B = 20.5 MPa

RA 400/500 $\Rightarrow$ σ_v = 400 MPa

a. globalni pravac Y

max.M_u = M_{yu} = 79.5 kNm/m (Y pravac, osa C: deo 2-4, osa A: deo 1-2)

pretp. a_{1y} = 3.0 cm $\Rightarrow$ $h_y = d - a_{1y} = 16 - 3.0 = 13.0$ cm

$$k = \frac{13.0}{\sqrt{\frac{79.5}{2.05}}} = 2.088 \Rightarrow \varepsilon_b/\varepsilon_a = 3.5/7.163‰ \; ; \; \bar{\mu} = 26.572\% \; ; \; \zeta = 0.863$$

$$A_{aY} = 26.572 \times 13.0 \times \frac{2.05}{40} = 17.70 \text{ cm}^2/\text{m}$$

Ø16 $\Rightarrow$ $a_a^{(1)}$ = 2.01 cm^2/m $\Rightarrow$ $e_a = \frac{100 \times a_a^{(1)}}{A_a} = \frac{100 \times 2.01}{17.70} = 11.4$ cm

usvojeno: **RØ16/10** (20.10 cm^2/m)

A_{ap} = 0.2×17.70 = 3.54 cm^2/m

pretp. Ø10 ($a_{ap}^{(1)}$ = 0.785 cm^2/m) $\Rightarrow$ $e_{ap} = \frac{100 \times a_{ap}^{(1)}}{A_{ap}} = \frac{100 \times 0.785}{3.54} = 22.2$ cm

usvojeno: **RØ10/20** (3.93 cm^2/m)

M_{yu} = 68.6 kNm/m (Y pravac, osa B, deo 2-3)

pretp. Ø16 $\Rightarrow$ $a_{1y} = 2.0 + 1.6/2 = 2.8$ cm $\Rightarrow$ $h_y = d - a_{1y} = 16 - 2.8 = 13.2$ cm

$$k = \frac{13.2}{\sqrt{\frac{68.6}{2.05}}} = 2.283 \Rightarrow \varepsilon_b/\varepsilon_a = 3.5/9.624‰ \; ; \; \bar{\mu} = 21.589\% \; ; \; \zeta = 0.889$$

$$A_{aY} = 21.589 \times 13.2 \times \frac{2.05}{40} = 14.60 \text{ cm}^2/\text{m}$$

A_{ap} = 0.2×14.60 = 2.92 cm^2/m

usvojeno: **RØ14/10** (15.40 cm^2/m)

RØ10/25 (3.14 cm^2/m) - podeona armatura

M_{yu} = 55.4 kNm/m (Y pravac, osa B, deo 1-2)

$$k = \frac{13.2}{\sqrt{\frac{55.4}{2.05}}} = 2.538 \Rightarrow \varepsilon_b/\varepsilon_a = 2.858/10‰ \; ; \; \bar{\mu} = 17.041\% \; ; \; \zeta = 0.911$$

$$A_{aY} = 17.041 \times 13.2 \times \frac{2.05}{40} = 11.53\ cm^2/m$$

A_{ap} = 0.2×11.53 = 2.31 cm^2/m

usvojeno: **RØ16/15** (13.40 cm^2/m)
RØ10/30 (2.62 cm^2/m) - podeona armatura

M_{yu} = 49.6 kNm/m (Y pravac, osa B, deo 3-4)

$$k = \frac{13.2}{\sqrt{\frac{49.6}{2.05}}} = 2.683 \Rightarrow \varepsilon_b/\varepsilon_a = 2.565/10‰ \ ; \ \bar{\mu} = 15.106\% \ ; \ \zeta = 0.920$$

$$A_{aY} = 15.106 \times 13.2 \times \frac{2.05}{40} = 10.22\ cm^2/m$$

A_{ap} = 0.2×10.22 = 2.04 cm^2/m > $A_{ap,min.}$ = 0.085×16 = 1.36 cm^2/m

usvojeno: **RØ14/15** (10.27 cm^2/m)
RØ10/30 (2.62 cm^2/m) - podeona armatura

b. globalni pravac X

max.M_{xu} = 61.4 kNm/m (X pravac, osa 3, deo A-B)

pretp. Ø14 $\Rightarrow$ a_{1x} = 2.0 + 1.6 + 1.4/2 = 4.3 cm $\Rightarrow$ $h_x = d - a_{1x}$ = 16 - 4.3 = 11.7 cm

$$k = \frac{11.7}{\sqrt{\frac{61.4}{2.05}}} = 2.138 \Rightarrow \varepsilon_b/\varepsilon_a = 3.5/7.777‰ \ ; \ \bar{\mu} = 25.125\% \ ; \ \zeta = 0.871$$

$$A_{aX} = 25.125 \times 11.7 \times \frac{2.05}{40} = 15.07\ cm^2/m$$

A_{ap} = 0.2×15.07 = 3.01 cm^2/m

usvojeno: **RØ14/10** (15.40 cm^2/m)
RØ10/25 (3.14 cm^2/m) - podeona armatura

Istom armaturom će biti armirani i preseci u osi 2 (delovi A-B i B-C) i u osi 3 (deo B-C) na kojima su momenti savijanja M_{xu} = 61.0, M_{xu} = 59.3 kNm/m odnosno M_{xu} = 54.4 kNm/m.

M_{xu} = 44.7 kNm/m (X pravac, osa 4, deo A-B)

$$k = \frac{11.7}{\sqrt{\frac{44.7}{2.05}}} = 2.505 \Rightarrow \varepsilon_b/\varepsilon_a = 2.935/10‰ \ ; \ \bar{\mu} = 17.537\% \ ; \ \zeta = 0.909$$

$$A_{aX} = 17.537 \times 11.7 \times \frac{2.05}{40} = 10.52\ cm^2/m$$

A_{ap} = 0.2×10.52 = 2.10 cm^2/m > $A_{ap,min.}$ = 0.085×16 = 1.36 cm^2/m

usvojeno: **RØ12/10** (11.31 cm^2/m)
RØ10/30 (2.62 cm^2/m) - podeona armatura

Dimenzionisanje - donja zona

a. globalni pravac Y

max.M_u = M_{yu} = 31.0 kNm/m (polje 2-3/A-B)

pretp. Ø12 $\Rightarrow$ a_{1y} = 2.0 + 1.2/2 = 2.6 cm $\Rightarrow$ $h_y = d - a_{1y} = 16 - 2.6 = 13.4$ cm

$$k = \frac{13.4}{\sqrt{\frac{31.0}{2.05}}} = 3.446 \Rightarrow \varepsilon_b/\varepsilon_a = 1.706/10‰ \; ; \; \bar{\mu} = 8.897\% \; ; \; \zeta = 0.947$$

$$A_{aY} = 8.897 \times 13.4 \times \frac{2.05}{40} = 6.11 \text{ cm}^2/\text{m}$$

usvojeno: **RØ12/15** (7.54 cm²/m)

Ostali preseci u donjoj zoni u Y pravcu će biti dimenzionisani pojednostavljeno, usvajajući da je krak unutrašnjih sila u svim razmatranim presecima konstantan i jednak kraku unutrašnjih sila $z_b = \zeta \times h = 0.947 \times 13.4 = 12.7$ cm koji odgovara najopterećenijem preseku:

polje 2-3/B-C: M_{yu} = 27.4 kNm/m $\Rightarrow$ $A_a \approx \frac{27.4}{31.0} \times 6.11 = 5.40$ cm²/m

usvojeno: **RØ12/20** (5.65 cm²/m)

polje 1-2/A-B: M_{yu} = 22.4 kNm/m $\Rightarrow$ $A_a \approx \frac{22.4}{31.0} \times 6.11 = 4.41$ cm²/m

usvojeno: **RØ10/15** (5.24 cm²/m)

Na isti način se armiraju i polja 1-2/B-C i 3-4/B-C.

polje 3-4/A-B: M_{yu} = 16.1 kNm/m $\Rightarrow$ $A_a \approx \frac{16.1}{31.0} \times 6.11 = 3.17$ cm²/m

usvojeno: **RØ10/20** (3.93 cm²/m)

b. globalni pravac X

max.M_{xu} = 27.4 kNm/m (polje 2-3/A-B)

pretp. Ø12 $\Rightarrow$ a_{1x} = 2.0 + 1.2 + 1.2/2 = 3.8 cm $\Rightarrow$ $h_x = d - a_{1x} = 16 - 3.8 = 12.2$ cm

$$k = \frac{12.2}{\sqrt{\frac{27.4}{2.05}}} = 3.336 \Rightarrow \varepsilon_b/\varepsilon_a = 1.788/10‰ \; ; \; \bar{\mu} = 9.520\% \; ; \; \zeta = 0.944$$

$$A_{aX} = 9.520 \times 12.2 \times \frac{2.05}{40} = 5.95 \text{ cm}^2/\text{m}$$

usvojeno: **RØ12/15** (7.54 cm²/m)

Istom armaturom se armira polje 1-2/B-C (M_{xu} = 26.8 kNm/m). Ostali preseci će biti dimenzionisani analogno Y pravcu, usvajajući $z_b = \zeta \times h = 0.944 \times 12.2 = 11.5$ cm, koji odgovara najopterećenijem preseku:

polje 3-4/A-B: M_{xu} = 23.3 kNm/m $\Rightarrow$ $A_a \approx \frac{23.3}{27.4} \times 5.95 = 5.05$ cm²/m

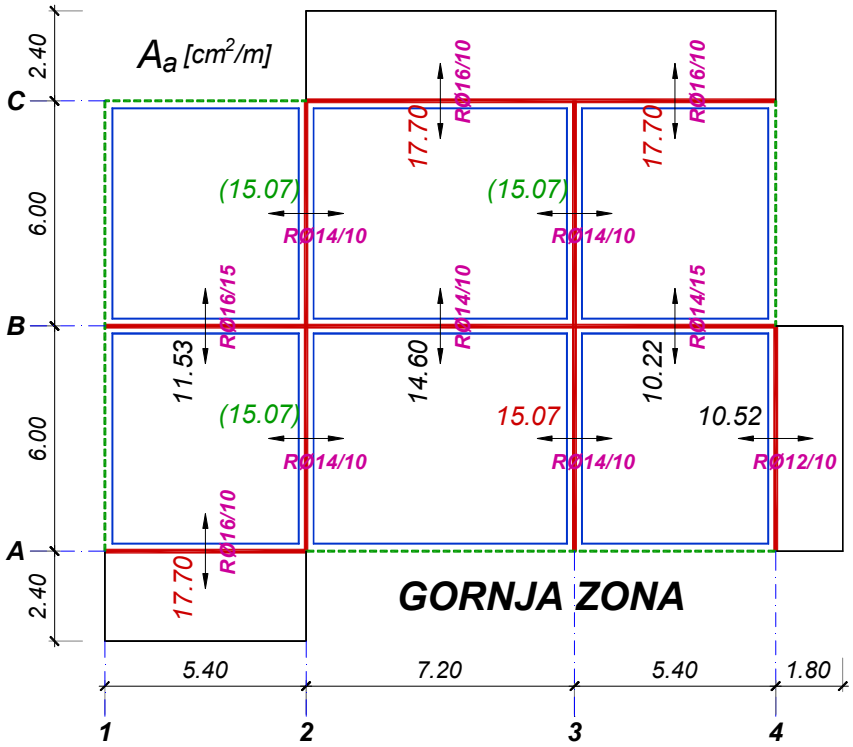
usvojeno: **RØ10/15** (5.24 cm²/m)

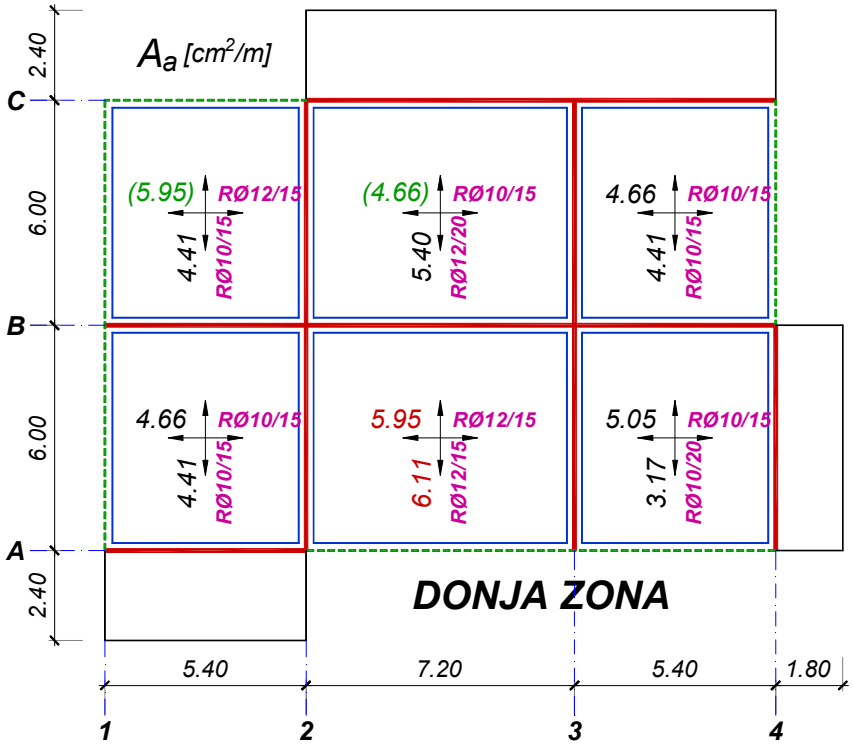
polje 1-2/A-B: M_{xu} = 21.5 kNm/m $\Rightarrow$ $A_a \approx \frac{21.5}{27.4} \times 5.95 = 4.66\ cm^2/m$

usvojeno: **RØ10/15** (5.24 cm^2/m)

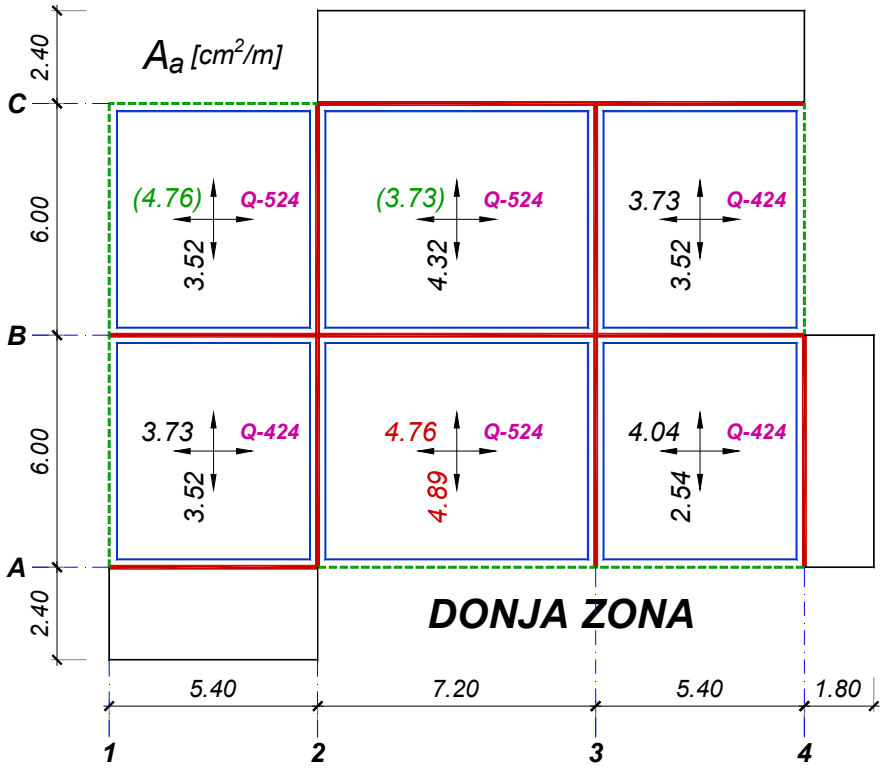
Na isti način se armiraju i polja 3-4/B-C i 2-3/B-C (M_{xu} = 20.3 kNm/m).

Rezultati proračuna (potrebna i usvojena armatura) prikazani su šematski na donjoj skici. Vrednosti u zagradama (zeleno) nisu direktno sračunate, već su usvojene zbog veoma sličnih vrednosti momenata savijanja.





Na sledećoj šemi je prikazana potrebna i usvojena površina armature u donjoj zoni u slučaju da se za armiranje koristi mrežasta armatura MA 500/560.



Određivanje opterećenja za grede

Jednako raspodeljeno opterećenje koje se sa pojedinačnih krstastih ploča prenosi na oslonačke grede, posebno za stalno i povremeno opterećenje, prikazano je tabelarno.

Ploča "A"

Konzolna ploča, raspona L=2.4 m.

$R_G = 6.0 \times 2.4 = 14.4$ kN/m $\qquad R_P = 10.0 \times 2.4 = 24.0$ kN/m

Ploča "B"

Konzolna ploča, raspona L=1.8 m.

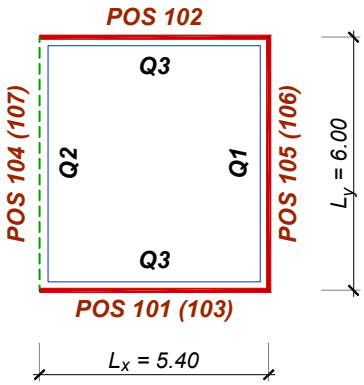
$R_G = 6.0 \times 1.8 = 10.8$ kN/m $\qquad R_P = 10.0 \times 1.8 = 18.0$ kN/m

Ploča "C"

$L_y / L_x = 6.0/5.4 = 1.11 \approx 1.1$

$G = 6.0 \times 5.4 \times 6.0 = 194.4$ kN

$P = 10.0 \times 5.4 \times 6.0 = 324.0$ kN



k		G kN	P kN	L m	g kN/m	p kN/m
0.282	Q_1	54.8	91.4	6	**9.14**	**15.23**
0.200	Q_2	38.9	64.8	6	**6.48**	**10.80**
0.259	Q_3	50.3	83.9	5.4	**9.32**	**15.54**

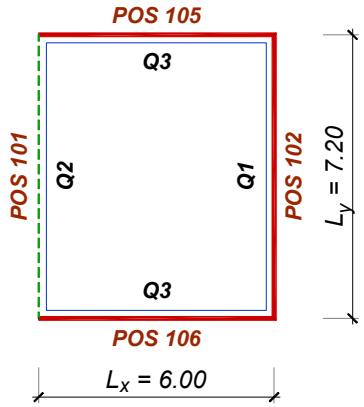
Ploča "D"

$L_y / L_x = 7.2/6.0 = 1.20$

$G = 6.0 \times 6.0 \times 7.2 = 259.2$ kN

$P = 10.0 \times 6.0 \times 7.2 = 432.0$ kN

		G	P	L	g	p
k		kN	kN	m	kN/m	kN/m
0.300	Q_1	77.8	129.6	7.2	**10.80**	**18.00**
0.210	Q_2	54.4	90.7	7.2	**7.56**	**12.60**
0.245	Q_3	63.5	105.8	6	**10.58**	**17.64**



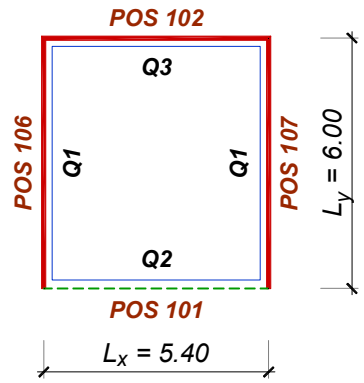
Ploča "E"

$L_y / L_x = 6.0/5.4 = 1.11 \approx 1.1$

$G = 6.0 \times 5.4 \times 6.0 = 194.4$ kN

$P = 10.0 \times 5.4 \times 6.0 = 324.0$ kN

		G	P	L	g	p
k		kN	kN	m	kN/m	kN/m
0.285	Q_1	55.4	92.3	6	**9.23**	**15.39**
0.182	Q_2	35.4	59.0	5.4	**6.55**	**10.92**
0.248	Q_3	48.2	80.4	5.4	**8.93**	**14.88**



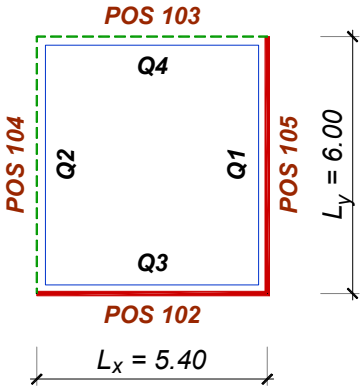
Ploča "F"

$L_y / L_x = 6.0/5.4 = 1.11 \approx 1.1$

$G = 6.0 \times 5.4 \times 6.0 = 194.4$ kN

$P = 10.0 \times 5.4 \times 6.0 = 324.0$ kN

		G	P	L	g	p
k		kN	kN	m	kN/m	kN/m
0.313	Q_1	60.8	101.4	6	**10.14**	**16.90**
0.217	Q_2	42.2	70.3	6	**7.03**	**11.72**
0.274	Q_3	53.3	88.8	5.4	**9.86**	**16.44**
0.196	Q_4	38.1	63.5	5.4	**7.06**	**11.76**



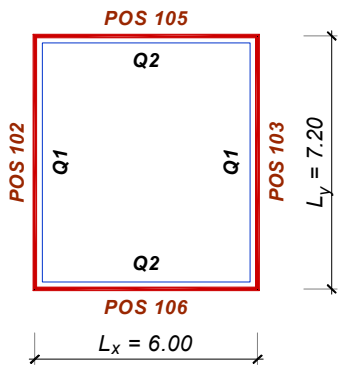
Ploča "G"

$L_y / L_x = 7.2/6.0 = 1.20$

$G = 6.0 \times 6.0 \times 7.2 = 259.2$ kN

$P = 10.0 \times 6.0 \times 7.2 = 432.0$ kN

		G	P	L	g	p
k		kN	kN	m	kN/m	kN/m
0.279	Q_1	72.3	120.5	7.2	**10.04**	**16.74**
0.221	Q_2	57.3	95.5	6	**9.55**	**15.91**



Jednako raspodeljeno opterećenje koje se sa ploče prenosi na pojedine grede, posebno za stalno, odnosno povremeno opterećenje, prikazano je na donjoj šemi. Stalnom opterećenju potrebno je dodati sopstvenu težinu greda.