Betonske konstrukcije 2

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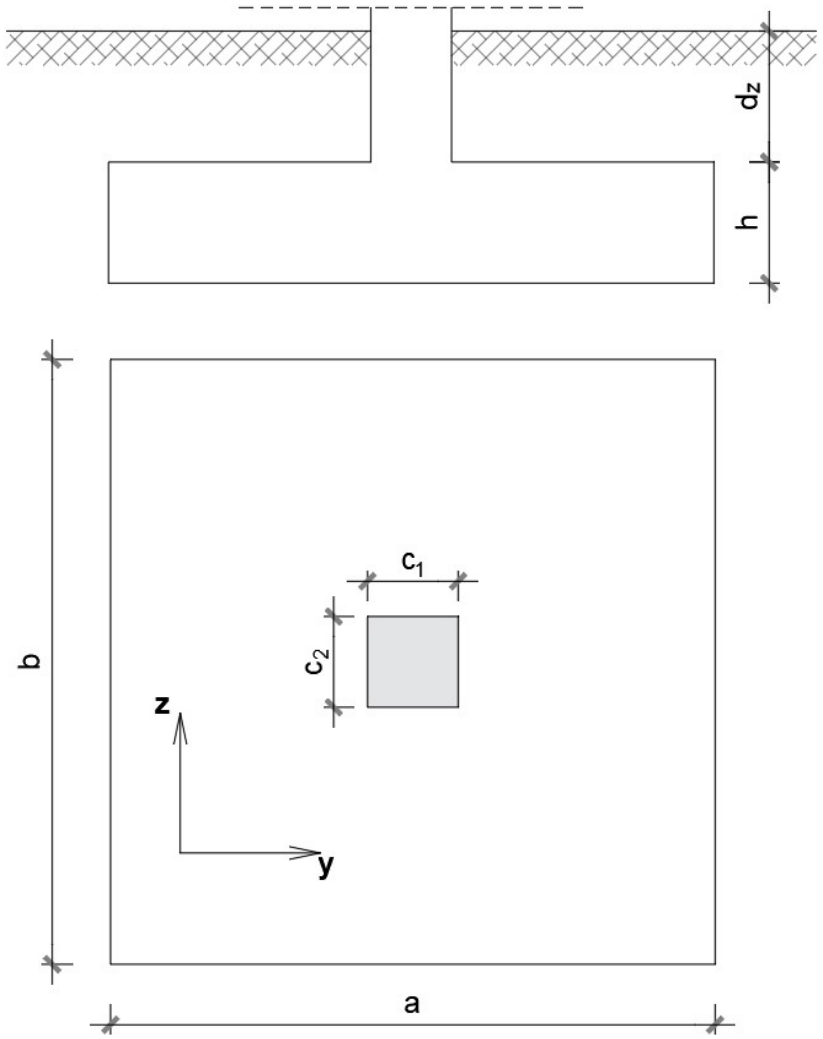
PROBOJ STUPA KROZ TEMELJ

Z. Sorić, T. Kišiček: Betonske konstrukcije 2

Str. 193 - 230



Geometrija:

$a = b = 330\ cm$

$c_1 = c_2 = 45\ cm$

$h = 60\ cm$

$d_z = 100\ cm$

Materijal:

Beton C25/30

$f_{ck} = 25\ N/mm^2$

$f_{cd} = \frac{f_{ck}}{\gamma_c} = \frac{25}{1.5} = 16.67\ \ N/mm^2$

Čelik B500B

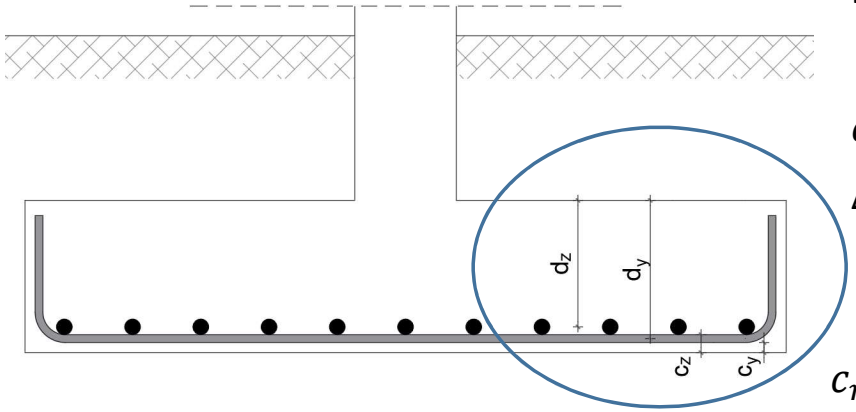
$f_{yk} = 500\ N/mm^2$

$f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500}{1.15} = 434.78\ \ N/mm^2$

Tlo: $\sigma_{Rd} = 300\frac{kN}{m^2}$ $\sigma_{ARd} = 360\frac{kN}{m^2}$

Zaštitni slojevi:

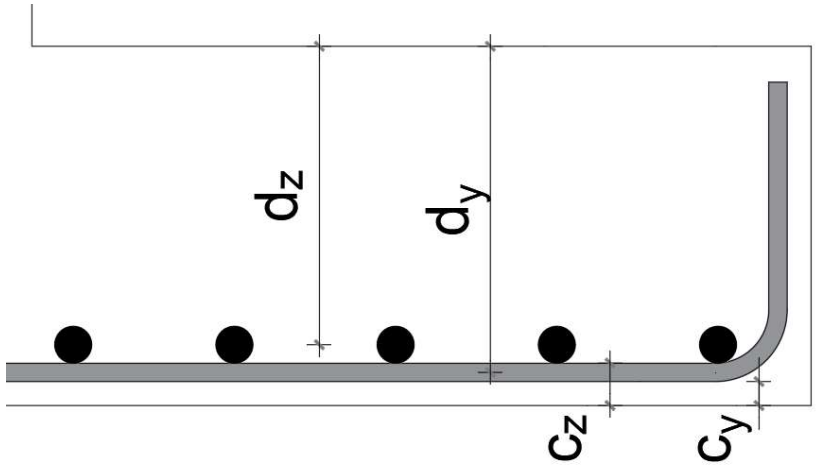
Nazivna debljina zaštitnog sloja: $c_{nom} = cmin + \Delta c_{dev}$



c_{min} minimalna debljina zaštitnog sloja

Δc_{dev} dodatak zbog odstupanja

$$c_{min} = max\left(c_{min,b}; c_{min,dur} + \Delta c_{dur,\gamma} - \Delta c_{dur,st} - \Delta c_{dur,add}; 10\ mm\right)$$



$c_{min,b}$ najmanji zaštitni sloj zbog prionljivosti

$c_{min,dur}$ najmanji zaštitni sloj zbog uvjeta okoliša

$\Delta c_{dur,\gamma}$ dodatni zaštitni sloj zbog sigurnosti

$\Delta c_{dur,st}$ smanjenje zaštitnog sloja za nehrđajući čelik

$\Delta c_{dur,add}$ smanjenje zaštitnog sloja zbog dodatne zaštite

Najveće zrno agregata: d_g = 20 mm
Proračunski vijek: 50 godina
Nema podataka o kontroli kvalitete

$$c_{nom} = c_{min} + \Delta c_{dev}$$

$$c_{min} = max\left(\boldsymbol{c_{min,b}}; c_{min,dur} + \Delta c_{dur,\gamma} - \Delta c_{dur,st} - \Delta c_{dur,add}; 10\ mm\right)$$

Najmanji zaštitni sloj obzirom na prionjivost	
Raspored šipki armature	$c_{min,b}$
pojedinačne	promjer šipke
u snopu	istovrijedni promjer ϕ_n
Ako je najveće zrno agregata veće od 32 mm, $c_{min,b}$ treba povećati za 5 mm.	

Pretpostavlja se promjer šipke za oba smjera ϕ14

$$c_{min,b} = 14\ mm$$

$$c_{nom} = c_{min} + \Delta c_{dev}$$

$$c_{min} = max\left(c_{min,b}; \boldsymbol{c_{min,dur}} + \Delta c_{dur,\gamma} - \Delta c_{dur,st} - \Delta c_{dur,add}; 10\ mm\right)$$

Najmanji zaštitni sloj zbog uvjeta okoliša $c_{min,dur}$

Određivanje razreda izloženosti (vidjeti tablicu 3.8 u Sorić, Kišiček: Betonske konstrukcije 1, str. 103):

2. Korozija prouzročena karbonatizacijom		
XC1	suhi ili stalno vlažni okoliš	elementi unutar građevina s niskom vlažnosti; beton stalno u vodi
XC2	vlažni, rijetko suhi	elementi dugotrajno izloženi vodi; temelji
XC3	umjereno vlažni	elementi unutar građevina s niskom ili umjerenom vlažnosti; vanjski elementi zaštićeni od kiše
XC4	izmjenično vlažni i suhi	elementi u dodiru s vodom, ali ne dugotrajno

$$c_{nom} = c_{min} + \Delta c_{dev}$$

$$c_{min} = max\left(c_{min,b}; \boldsymbol{c_{min,dur}} + \Delta c_{dur,\gamma} - \Delta c_{dur,st} - \Delta c_{dur,add}; 10\ mm\right)$$

Najmanji zaštitni sloj zbog uvjeta okoliša $c_{min,dur}$

Određivanje razreda konstrukcije – početni razred je S4:

Razred konstrukcije							
Kriterij	Razred izloženosti						
	X0	XC1	XC2/XC3	XC4	XD1	XD2/XS1	XD2/XS2/XS3
proračunski vijek 100 god.	povećati razred za 2	povećati razred za 2	~~povećati razred za 2~~	povećati razred za 2	povećati razred za 2	povećati razred za 2	povećati razred za 2
razred čvrstoće	≥ C30/37 smanjiti razred za 1	≥ C30/37 smanjiti razred za 1	~~≥ C35/45 smanjiti razred za 1~~	≥ C40/50 smanjiti razred za 1	≥ C40/50 smanjiti razred za 1	≥ C40/50 smanjiti razred za 1	≥ C45/55 smanjiti razred za 1
pločasti elementi	smanjiti razred za 1	smanjiti razred za 1	smanjiti razred za 1	smanjiti razred za 1	smanjiti razred za 1	smanjiti razred za 1	smanjiti razred za 1
posebna kontrola kvalitete betona	smanjiti razred za 1	smanjiti razred za 1	~~smanjiti razred za 1~~	smanjiti razred za 1	smanjiti razred za 1	smanjiti razred za 1	smanjiti razred za 1

$$c_{nom} = c_{min} + \Delta c_{dev}$$

$$c_{min} = max\left(c_{min,b}; \boldsymbol{c_{min,dur}} + \Delta c_{dur,\gamma} - \Delta c_{dur,st} - \Delta c_{dur,add}; 10\ mm\right)$$

Najmanji zaštitni sloj zbog uvjeta okoliša $c_{min,dur}$

Određivanje razreda konstrukcije – umanjiti razred za 1:

Uvjeti okoliša za određivanje $c_{min,dur}$ [mm]							
Razred konstrukcije	Razred izloženosti						
	X0	XC1	XC2/XC3	XC4	XD1/XS1	XD2/XS2	XD3/XS3
S1	10	10	10	15	20	25	30
S2	10	10	15	20	25	30	35
S3	10	10	20	25	30	35	40
S4	10	15	25	30	35	40	45
S5	15	20	30	35	40	45	50
S6	20	25	35	40	45	50	55

$$c_{min,dur} = 20\ mm$$

$$c_{nom} = c_{min} + \Delta c_{dev}$$

$$c_{min} = max\left(c_{min,b}; \boldsymbol{c_{min,dur}} + \Delta c_{dur,\gamma} - \Delta c_{dur,st} - \Delta c_{dur,add}; 10\ mm\right)$$

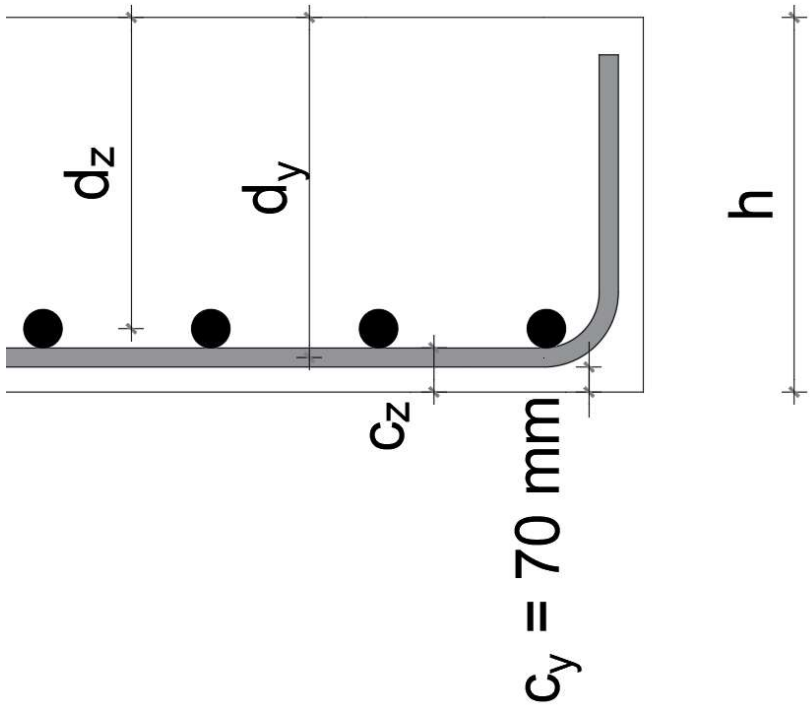
$$\Delta c_{dur,\gamma} = 0$$
$$\Delta c_{dur,st} = 0$$
$$\Delta c_{dur,add} = 0$$

$$c_{min} = max(14\ mm; \boldsymbol{20\ mm}; 10\ mm)$$

$$\Delta c_{dev} = 10\ mm$$

Posebna odredba za temelje: ako se beton izlijeva na poravnatu podlogu treba dodati još 40 mm!

$$\boldsymbol{c_{nom} = 20 + 10 + 40 = 70\ mm}$$

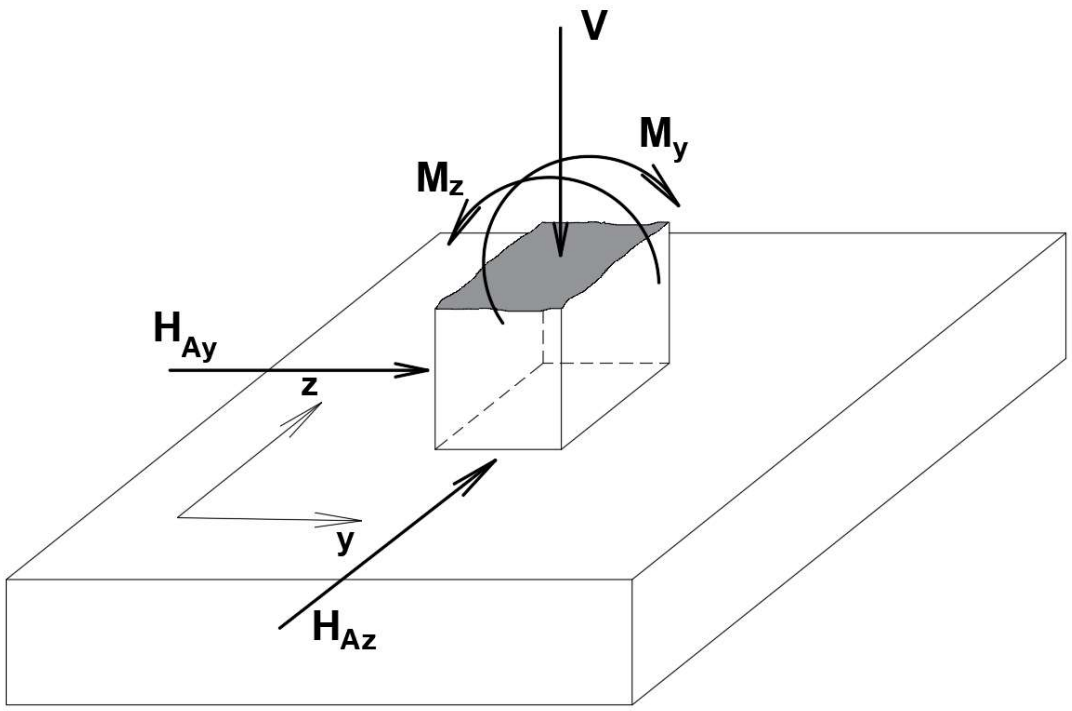


Statičke visine:

$$d_y = h - c_y - \frac{\phi_y}{2} = 60 - 7 - \frac{1.4}{2} = 52.3\ cm$$

$$d_z = d_y - \frac{\phi_y}{2} - \frac{\phi_z}{2} = 52.3 - \frac{1.4}{2} - \frac{1.4}{2} = 50.9\ cm$$

$$d = \frac{d_y + d_z}{2} = \frac{52.3 + 50.9}{2} = 51.6\ cm$$



Opterećenja (iz statičkog proračuna):

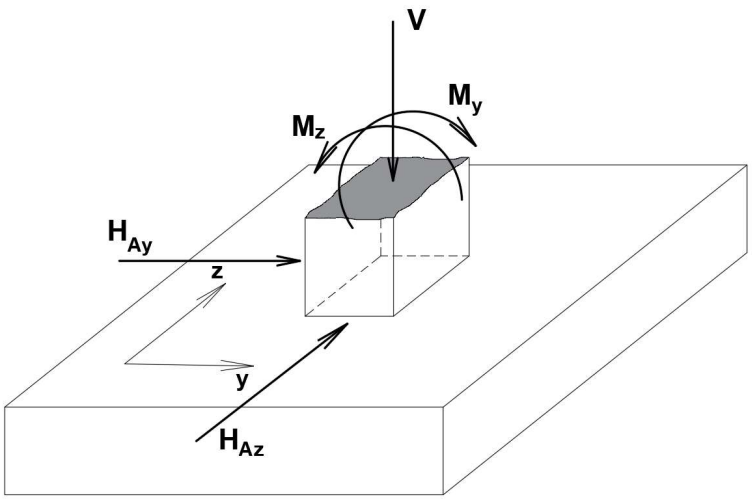
$V_G = 550.00\ kN$ $V_Q = 270.00\ kN$

$M_{G,y} = 105.00\ kNm$ $M_{Q,y} = 95.00\ kNm$

$M_{G,z} = 135.00\ kNm$ $M_{Q,z} = 115.00\ kNm$

$M_{A,y} = 405.00\ kNm$ $M_{A,z} = 205.00\ kNm$

$H_{A,y} = 110.00\ kN$ $H_{A,z} = 68.00\ kN$



Opterećenja (iz statičkog proračuna):

Osnovna: $\sum \gamma_{G,i} \cdot G_i + \gamma_{Q,1} \cdot Q_1 + \sum \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_i$

Seizmička: $\sum G_i + A_{Ed} + \sum \psi_{2,i} \cdot Q_i$

Osnovna kombinacija opterećenja:

$V_{Ed} = 1.35 \cdot (550.00 + 0.6 \cdot 3.3 \cdot 3.3 \cdot 25.00) + 1.50 \cdot 270 = 1368.02\ kN$

$M_{Ed,y} = 1.35 \cdot 105.00 + 1.50 \cdot 95.00 = 284.25\ kNm$

$M_{Ed,z} = 1.35 \cdot 135.00 + 1.50 \cdot 115.00 = 354.75\ kNm$

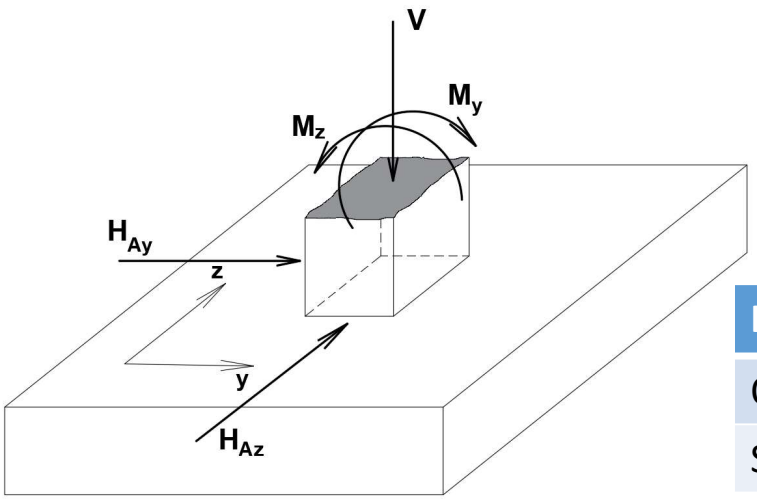
Seizmička kombinacija opterećenja:

$M_{Ed,y} = 105.00 + 405.00 + 0.3 \cdot 95.00 + 68.00 \cdot 0.6 = 579.30\ kNm$

$M_{Ed,z} = 135.00 + 205.00 + 0.3 \cdot 115.00 + 110.00 \cdot 0.6 = 440.50\ kNm$

$V_{Ed} = 550.00 + 0.6 \cdot 3.3 \cdot 3.3 \cdot 25.00 + 270 = 983.35\ kN$

$H_{AEd,y} = 110.00\ kN \qquad H_{AEd,z} = 68.00\ kN$



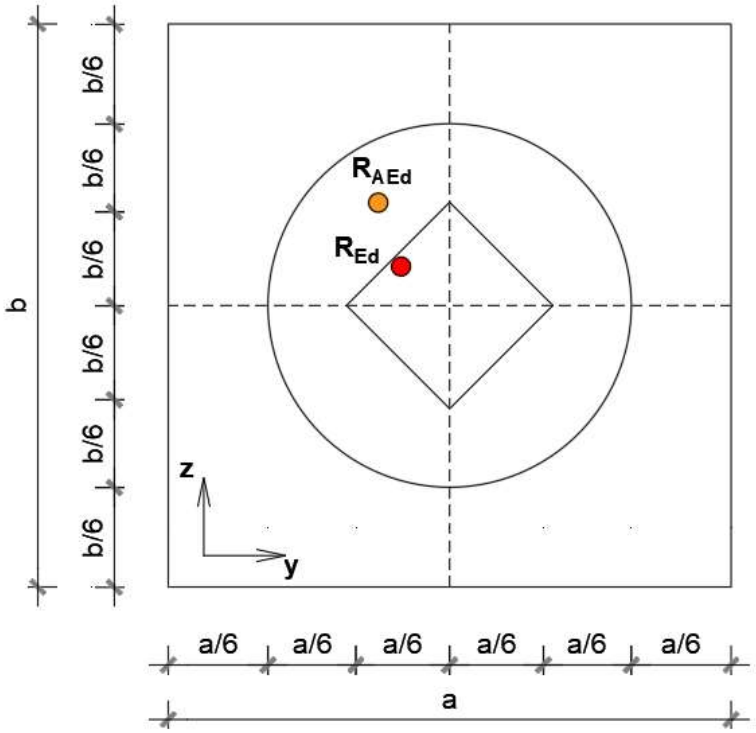
Opterećenja (iz statičkog proračuna):

Osnovna: $\sum \gamma_{G,i} \cdot G_i + \gamma_{Q,1} \cdot Q_1 + \sum \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_i$

Seizmička: $\sum G_i + A_{Ed} + \sum \psi_{2,i} \cdot Q_i$

Kombinacija	V_{Ed}	$M_{Ed,y}$	$M_{Ed,z}$	$H_{Ed,y}$	$H_{Ed,z}$
Osnovna	1368.02	284.25	354.75	0.00	0.00
Seizmička	983.35	579.30	440.50	110.00	68.00

Stabilnost temelja



Ekscentriciteti sile V_{Ed}:

Za osnovnu kombinaciju:

$$e_y = \frac{M_{Ed,z}}{V_{Ed}} = \frac{35475}{1368.02} = 25.93\ cm \qquad e_z = \frac{M_{Ed,y}}{V_{Ed}} = \frac{28425}{1368.02} = 20.77\ cm$$

Za seizmičku kombinaciju:

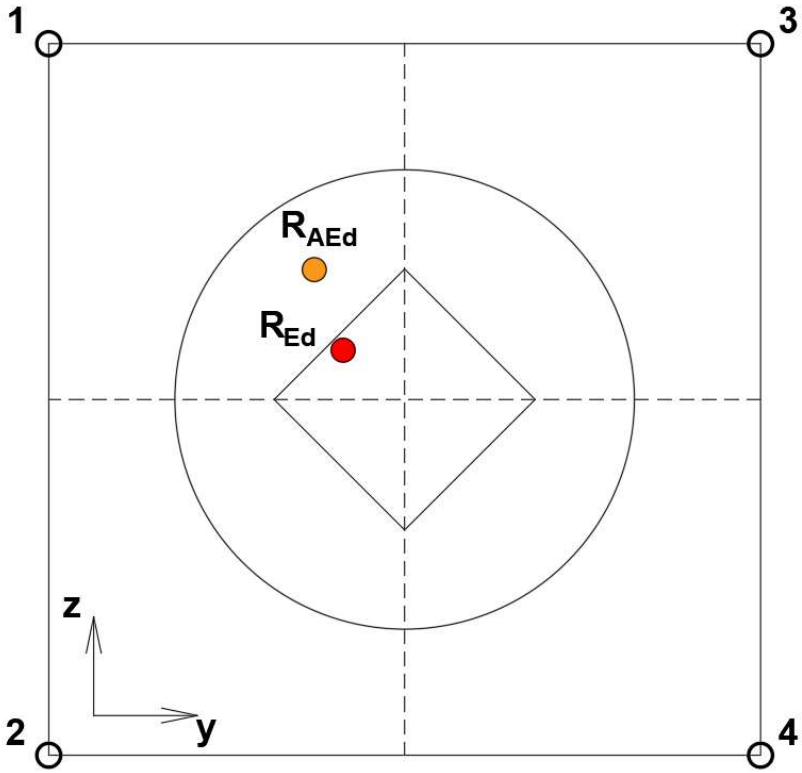
$$e_y = \frac{M_{Ed,z}}{V_{Ed}} = \frac{44050}{983.35} = 44.79\ cm \qquad e_z = \frac{M_{Ed,y}}{V_{Ed}} = \frac{57930}{983.35} = 58.91\ cm$$

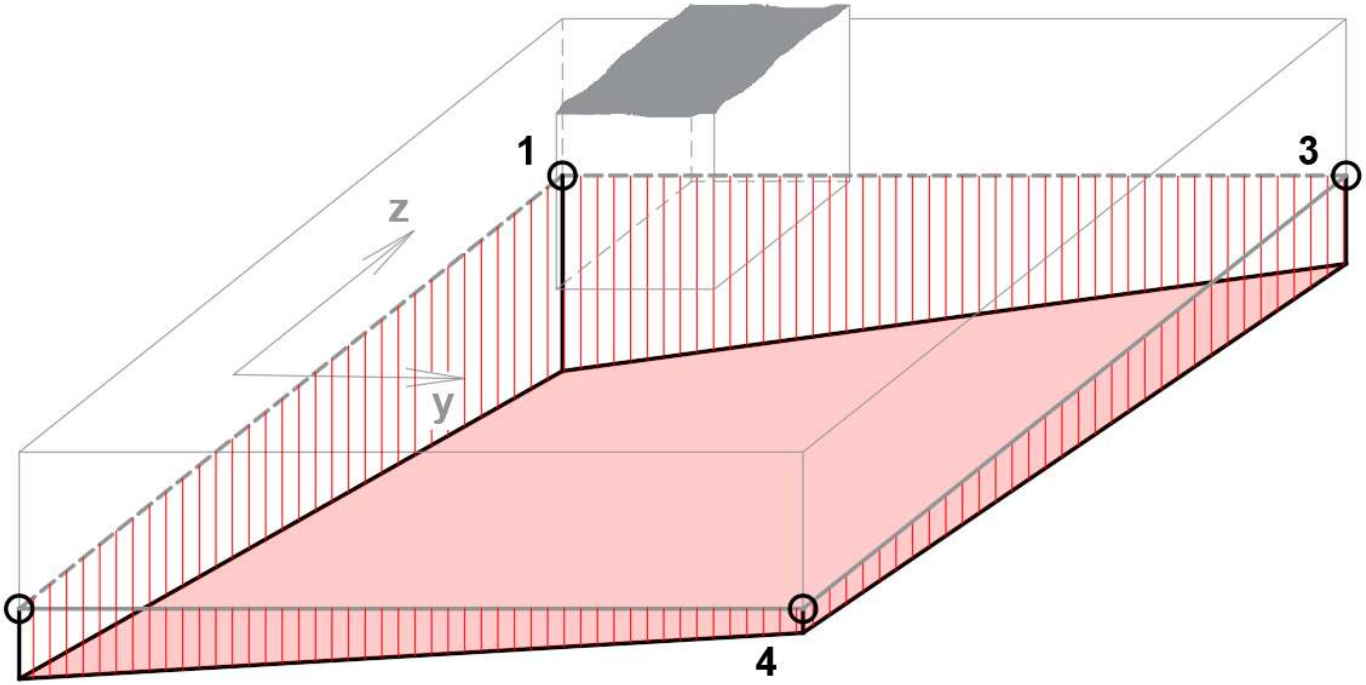
Kontrola stabilnosti:

$$\frac{e_y}{a} + \frac{e_z}{b} \le \frac{1}{6} \rightarrow \frac{25.93}{330} + \frac{20.77}{330} = 0.14 < 0.16$$

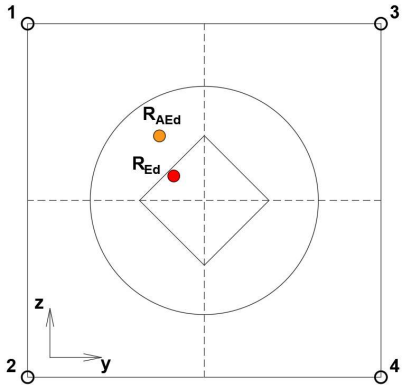
$$\left(\frac{e_y}{a}\right)^2 + \left(\frac{e_z}{b}\right)^2 \le \frac{1}{9} \rightarrow \left(\frac{44.79}{330}\right)^2 + \left(\frac{58.91}{330}\right)^2 = 0.05 < 0.11$$

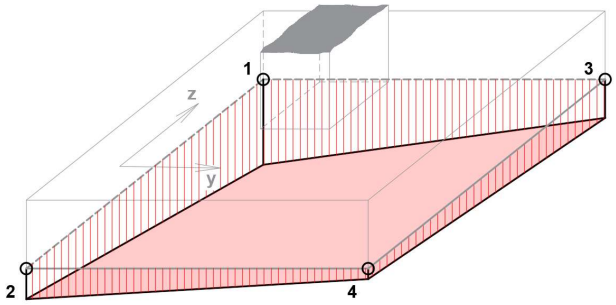
Naprezanja u tlu ispod temeljne stope





Naprezanja u tlu ispod temeljne stope





Ploština temelja: $A = 3.3 \cdot 3.3 = 10.89\ m^2$

Momenti otpora: $W_x = W_y = \frac{3.3+3.3^2}{6} = 5.99\ m^3$

Nosivost tla: $\sigma_{Rd} = 300\,\frac{kN}{m^2}$ $\sigma_{ARd} = 360\,\frac{kN}{m^2}$

NAPOMENA: težina zemlje iznad temeljne stope smije se uzeti u obzir.

Osnovna kombinacija:

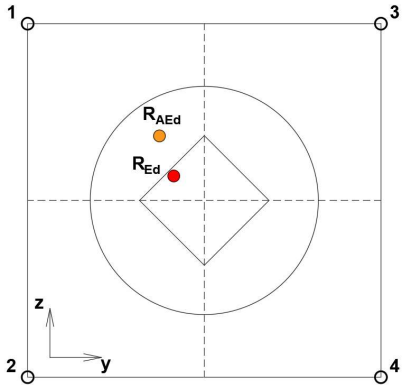
$$\sigma_1 = \frac{V_{Ed}}{\mathrm{A}} + \frac{M_{Ed,y}}{W_y} + \frac{M_{Ed,z}}{W_z} = \frac{1368.02}{10.89} + \frac{284.25}{5.99} + \frac{354.75}{5.99} = 232.30\ kN/m^2$$

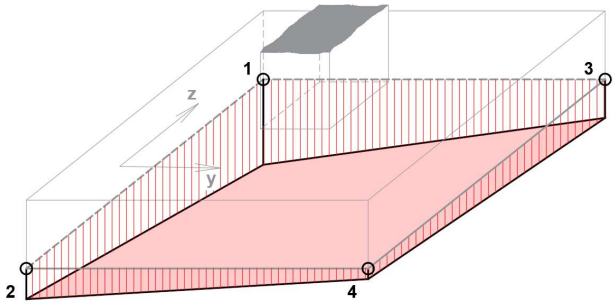
$$\sigma_2 = \frac{V_{Ed}}{\mathrm{A}} + \frac{M_{Ed,y}}{W_y} - \frac{M_{Ed,z}}{W_z} = \frac{1368.02}{10.89} + \frac{284.25}{5.99} - \frac{354.75}{5.99} = 113.85\ kN/m^2$$

$$\sigma_3 = \frac{V_{Ed}}{\mathrm{A}} - \frac{M_{Ed,y}}{W_y} + \frac{M_{Ed,z}}{W_z} = \frac{1368.02}{10.89} - \frac{284.25}{5.99} + \frac{354.75}{5.99} = 137.39\ kN/m^2$$

$$\sigma_4 = \frac{V_{Ed}}{\mathrm{A}} - \frac{M_{Ed,y}}{W_y} - \frac{M_{Ed,z}}{W_z} = \frac{1368.02}{10.89} - \frac{284.25}{5.99} - \frac{354.75}{5.99} = 18.94\ kN/m^2$$

Naprezanja u tlu ispod temeljne stope





Ploština temelja: $A = 3.3 \cdot 3.3 = 10.89\ m^2$

Momenti otpora: $W_x = W_y = \frac{3.3+3.3^2}{6} = 5.99\ m^3$

Nosivost tla: $\sigma_{Rd} = 300\,\frac{kN}{m^2}$ $\sigma_{ARd} = 360\,\frac{kN}{m^2}$

NAPOMENA: težina zemlje iznad temeljne stope smije se uzeti u obzir.

Seizmička kombinacija:

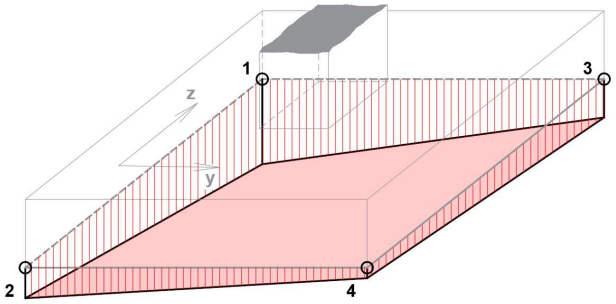
$$\sigma_1 = \frac{V_{Ed}}{\mathrm{A}} + \frac{M_{Ed,y}}{W_y} + \frac{M_{Ed,z}}{W_z} = \frac{983.35}{10.89} + \frac{579.30}{5.99} + \frac{440.50}{5.99} = 260.54\ kN/m^2$$

$$\sigma_2 = \frac{V_{Ed}}{\mathrm{A}} + \frac{M_{Ed,y}}{W_y} - \frac{M_{Ed,z}}{W_z} = \frac{983.35}{10.89} + \frac{579.30}{5.99} - \frac{440.50}{5.99} = 113.47\ kN/m^2$$

$$\sigma_3 = \frac{V_{Ed}}{\mathrm{A}} - \frac{M_{Ed,y}}{W_y} + \frac{M_{Ed,z}}{W_z} = \frac{983.35}{10.89} - \frac{579.30}{5.99} + \frac{440.50}{5.99} = 67.12\ kN/m^2$$

$$\sigma_4 = \frac{V_{Ed}}{\mathrm{A}} - \frac{M_{Ed,y}}{W_y} - \frac{M_{Ed,z}}{W_z} = \frac{983.35}{10.89} - \frac{579.30}{5.99} - \frac{440.50}{5.99} = -79.95\ kN/m^2$$

Dimenzioniranje temeljne stope na savijanje



Kombinacija	σ_1	σ_2	σ_3	σ_4
Osnovna	232.30	113.85	137.39	18.94
Seizmička	260.54	113.47	67.12	−79.95

Osnovna kombinacija za $M_{Ed,z}$:

$$\sigma' = \frac{\sigma_1 + \sigma_2}{2} = \frac{232.30 + 113.85}{2} = 173{,}07\ kN/m^2$$

$$\sigma'' = \frac{\sigma_3 + \sigma_4}{2} = \frac{137.39 + 18.94}{2} = 78.16\ kN/m^2$$

$$M_{Ed,z} = \frac{5 \cdot \sigma' + \sigma''}{48} a^3 = \frac{5 \cdot 173.07 + 78.16}{48} \cdot 3.30^3 = 706.39\ kNm$$

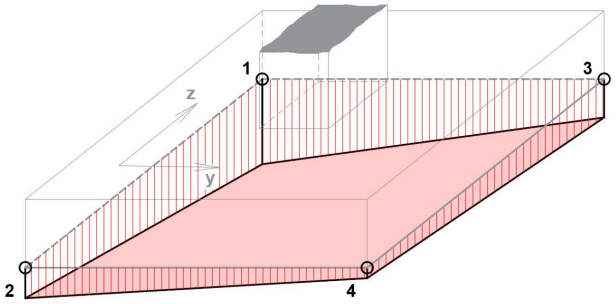
Osnovna kombinacija za $M_{Ed,y}$:

$$\sigma' = \frac{\sigma_1 + \sigma_3}{2} = \frac{232.30 + 137.39}{2} = 184.84\ kN/m^2$$

$$\sigma'' = \frac{\sigma_2 + \sigma_4}{2} = \frac{113.85 + 18.94}{2} = 66.39\ kN/m^2$$

$$M_{Ed,y} = \frac{5 \cdot \sigma' + \sigma''}{48} b^3 = \frac{5 \cdot 184.84 + 66.39}{48} \cdot 3.30^3 = 741.64\ kNm$$

Dimenzioniranje temeljne stope na savijanje



Kombinacija	σ_1	σ_2	σ_3	σ_4
Osnovna	232.30	113.85	137.39	18.94
Seizmička	260.54	113.47	67.12	−79.95

Seizmička kombinacija za $M_{Ed,z}$: $\sigma' = \frac{\sigma_1 + \sigma_2}{2} = \frac{260.54 + 113.47}{2} = 187.00\ kN/m^2$

$$\sigma'' = \frac{\sigma_3 + \sigma_4}{2} = \frac{67.12 - 79.95}{2} = -6.41\ kN/m^2$$

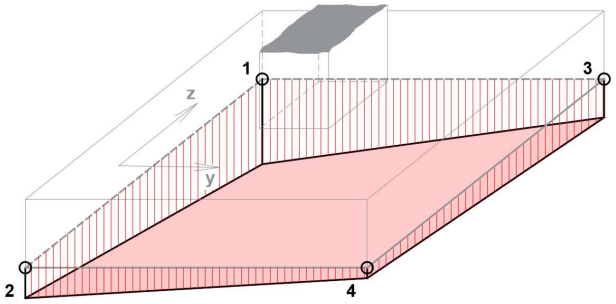
$$M_{Ed,z} = \frac{5 \cdot \sigma' + \sigma''}{48} a^3 = \frac{5 \cdot 187.00 - 6.41}{48} \cdot 3.30^3 = 695.22\ kNm$$

Seizmička kombinacija za $M_{Ed,y}$: $\sigma' = \frac{\sigma_1 + \sigma_3}{2} = \frac{260.54 + 67.12}{2} = 163.83\ kN/m^2$

$$\sigma'' = \frac{\sigma_2 + \sigma_4}{2} = \frac{113.47 - 79.95}{2} = -33.24\ kN/m^2$$

$$M_{Ed,z} = \frac{5 \cdot \sigma' + \sigma''}{48} b^3 = \frac{5 \cdot 163.83 - 33.24}{48} \cdot 3.30^3 = 588.40\ kNm$$

Dimenzioniranje temeljne stope na savijanje

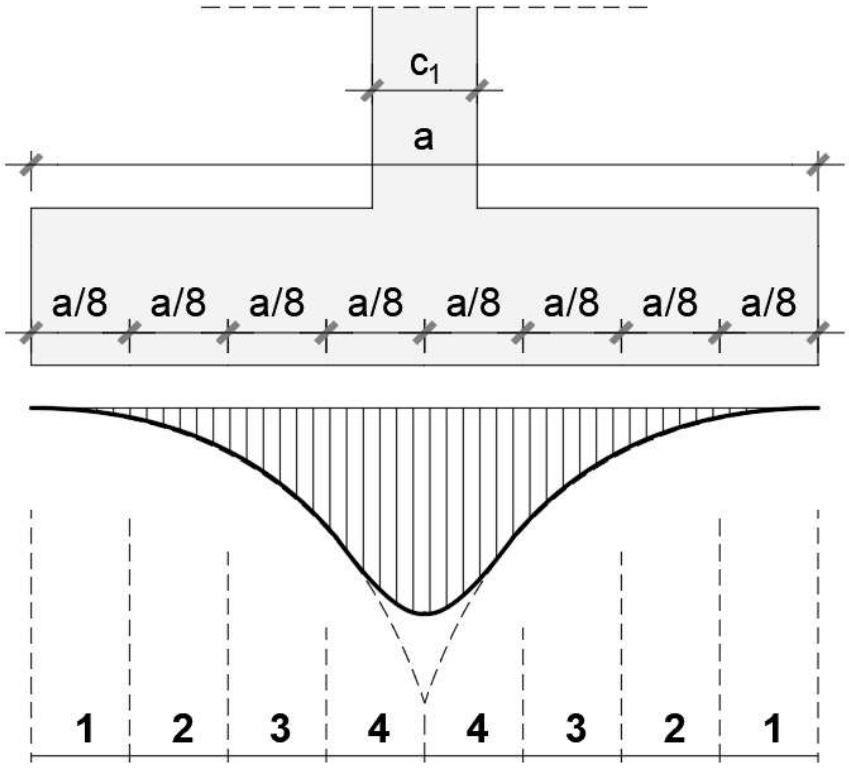


Kombinacija	$M_{Ed,y}$	$M_{Ed,z}$
Osnovna	**741.64**	706.39
Seizmička	588.40	695.22

$$\mu_{Ed} = \frac{M_{Ed,y}}{b \cdot d^2 \cdot f_{cd}} = \frac{74164}{330 \cdot 51.6^2 \cdot 1.667} = 0.050 \rightarrow \begin{array}{l} \xi = 0.083 \\ \zeta = 0.970 \\ \varepsilon_{c2} = -1.8\ ^o/_{oo} \\ \varepsilon_{s1} = -20.0\ ^o/_{oo} \end{array}$$

$$A_{s1} = \frac{M_{Ed,y}}{\zeta \cdot d \cdot f_{yd}} = \frac{74164}{0.970 \cdot 51.6 \cdot 43.47} = 34.08\ cm^2$$

Dimenzioniranje temeljne stope na savijanje



	$\frac{c_1}{a}, \frac{c_2}{b}$		
Traka	0.10	0.20	0.30
1	0.07	0.08	0.09
2	0.10	0.10	0.11
3	0.14	0.14	0.14
4	0.19	0.18	0.16
$\sum$	0.50	0.50	0.50

$$\frac{c_1}{a} = \frac{c_2}{b} = \frac{45}{330} = 0.13$$

$$\alpha_1 = 0.073$$
$$\alpha_2 = 0.10$$
$$\alpha_3 = 0.14$$
$$\alpha_4 = 0.187$$

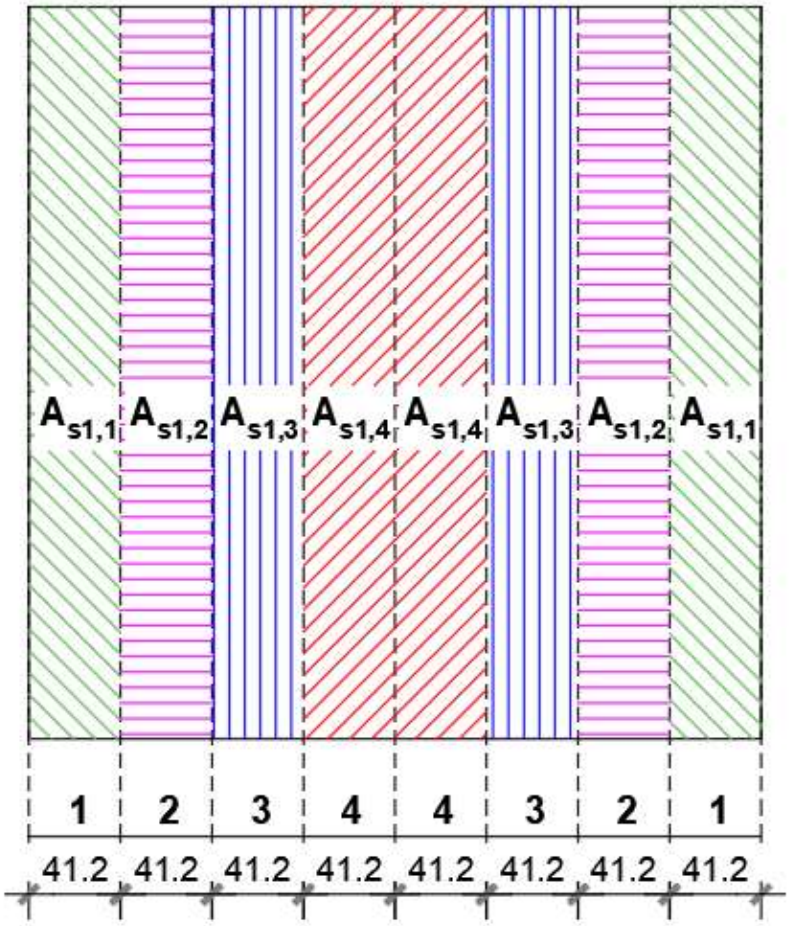
$A_{s1,1} = 0.073 \cdot 34.08 = 2.48\ cm^2$ $3\phi14\ (4.62\ cm^2)$

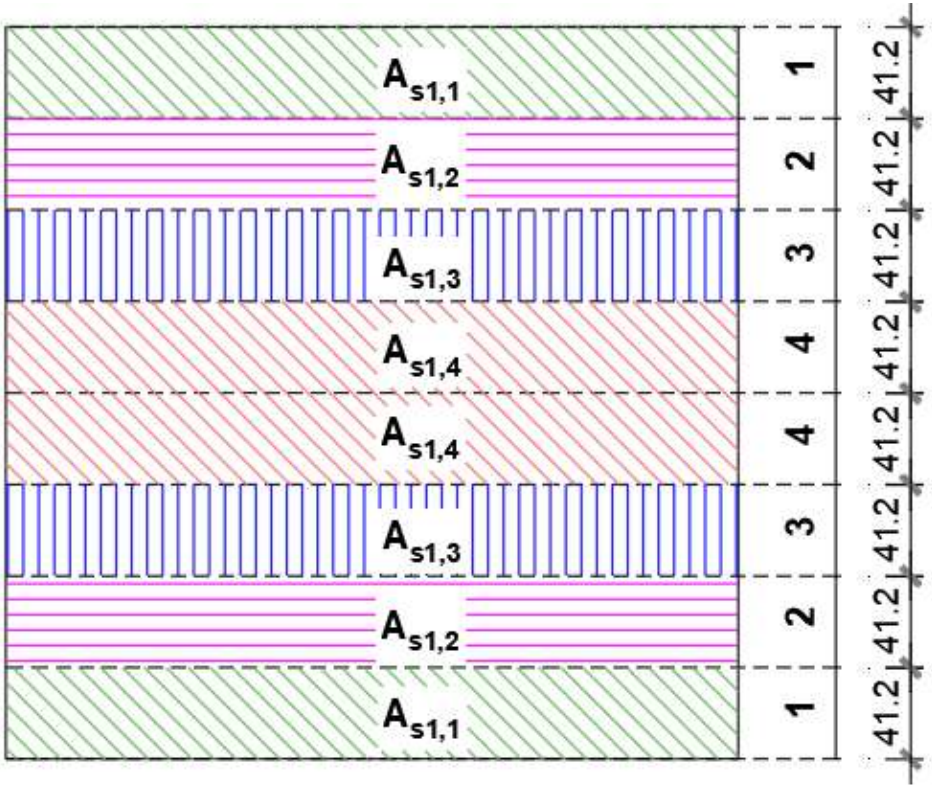
$A_{s1,2} = 0.10 \cdot 34.08 = 3.41\ cm^2$ $3\phi14\ (4.62\ cm^2)$

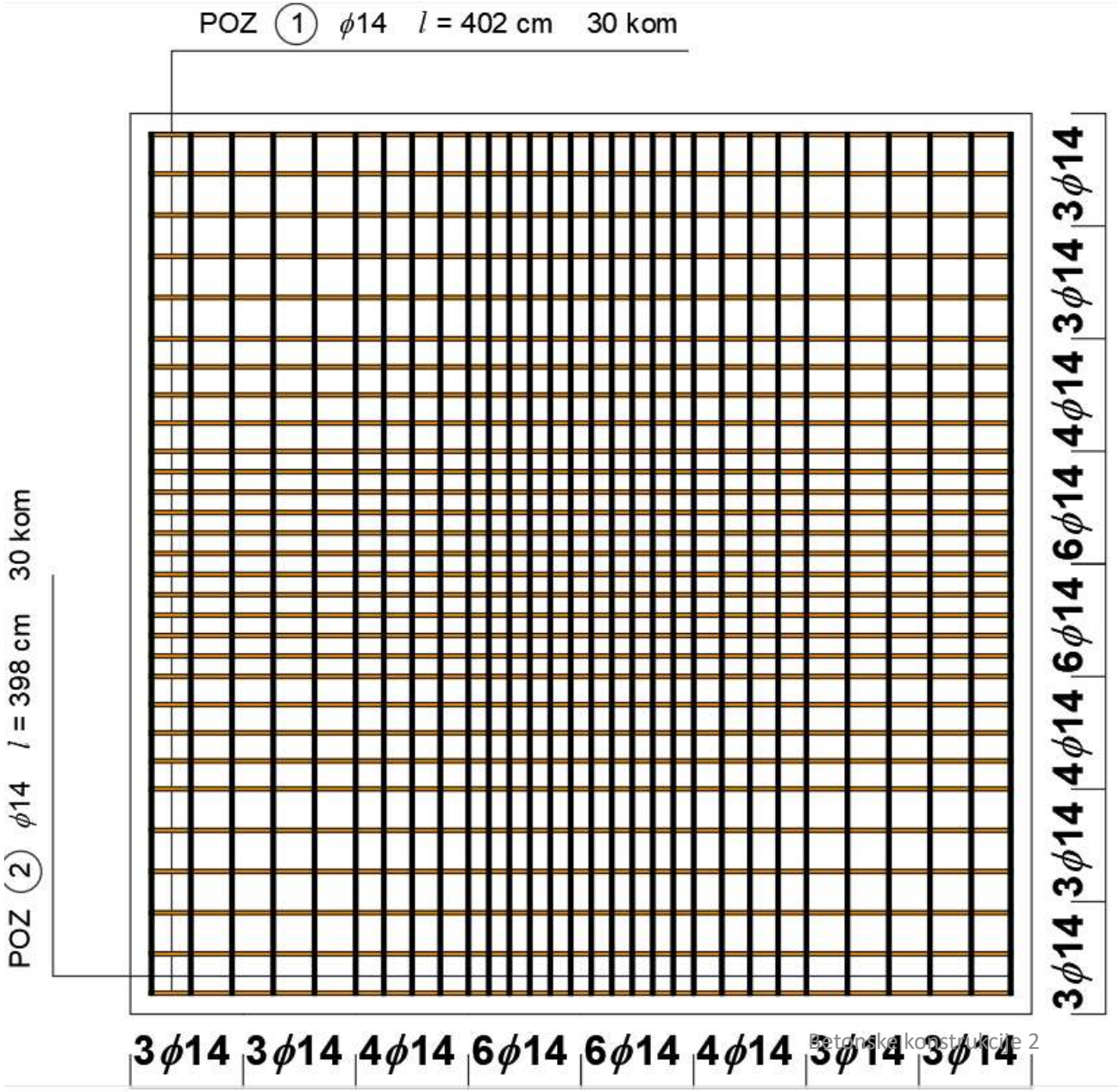
$A_{s1,3} = 0.14 \cdot 34.08 = 4.77\ cm^2$ $4\phi14\ (6.16\ cm^2)$

$A_{s1,4} = 0.187 \cdot 34.08 = 6.37\ cm^2$ $5\phi14\ (7.70\ cm^2)$

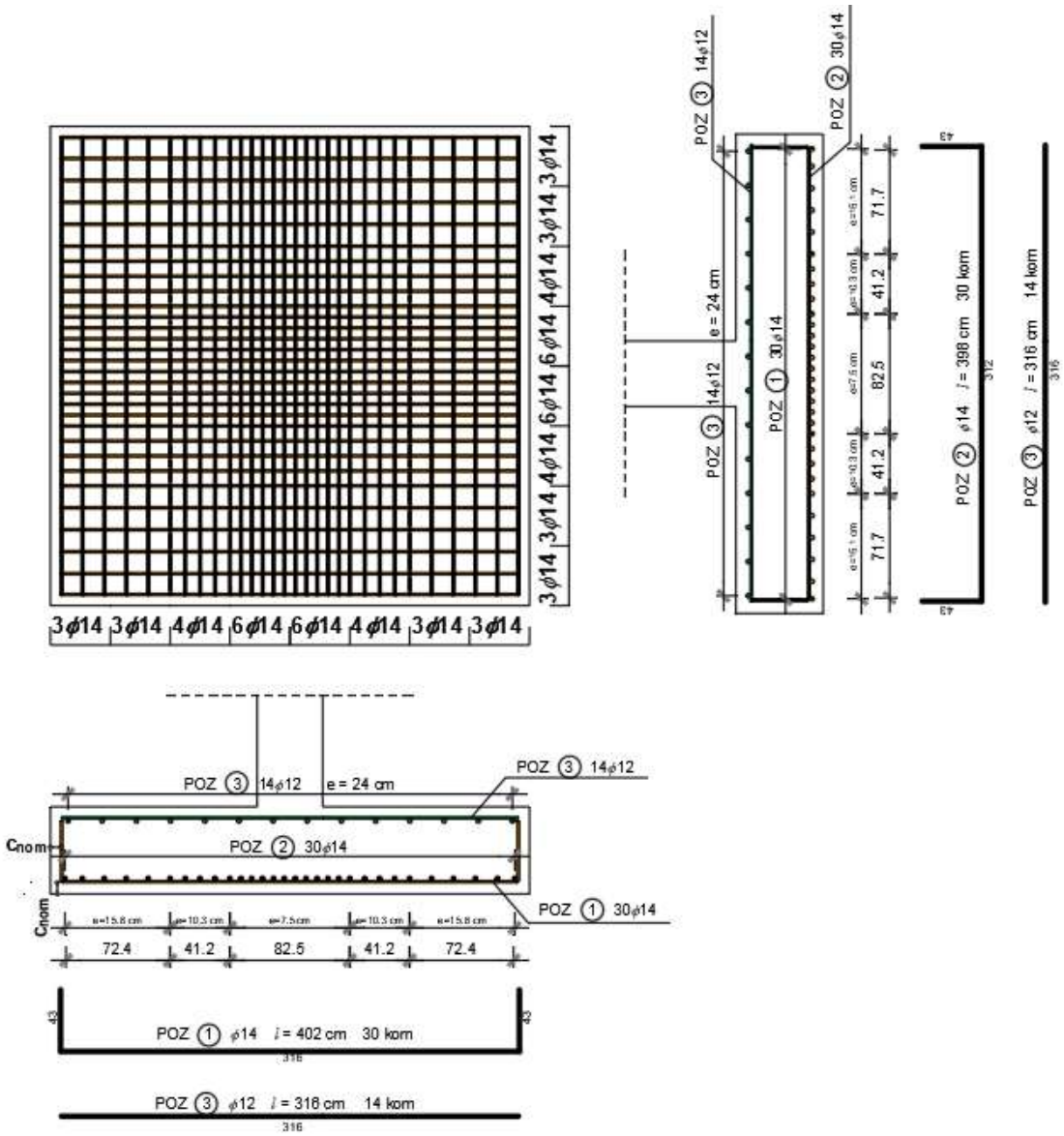
Zone armiranja

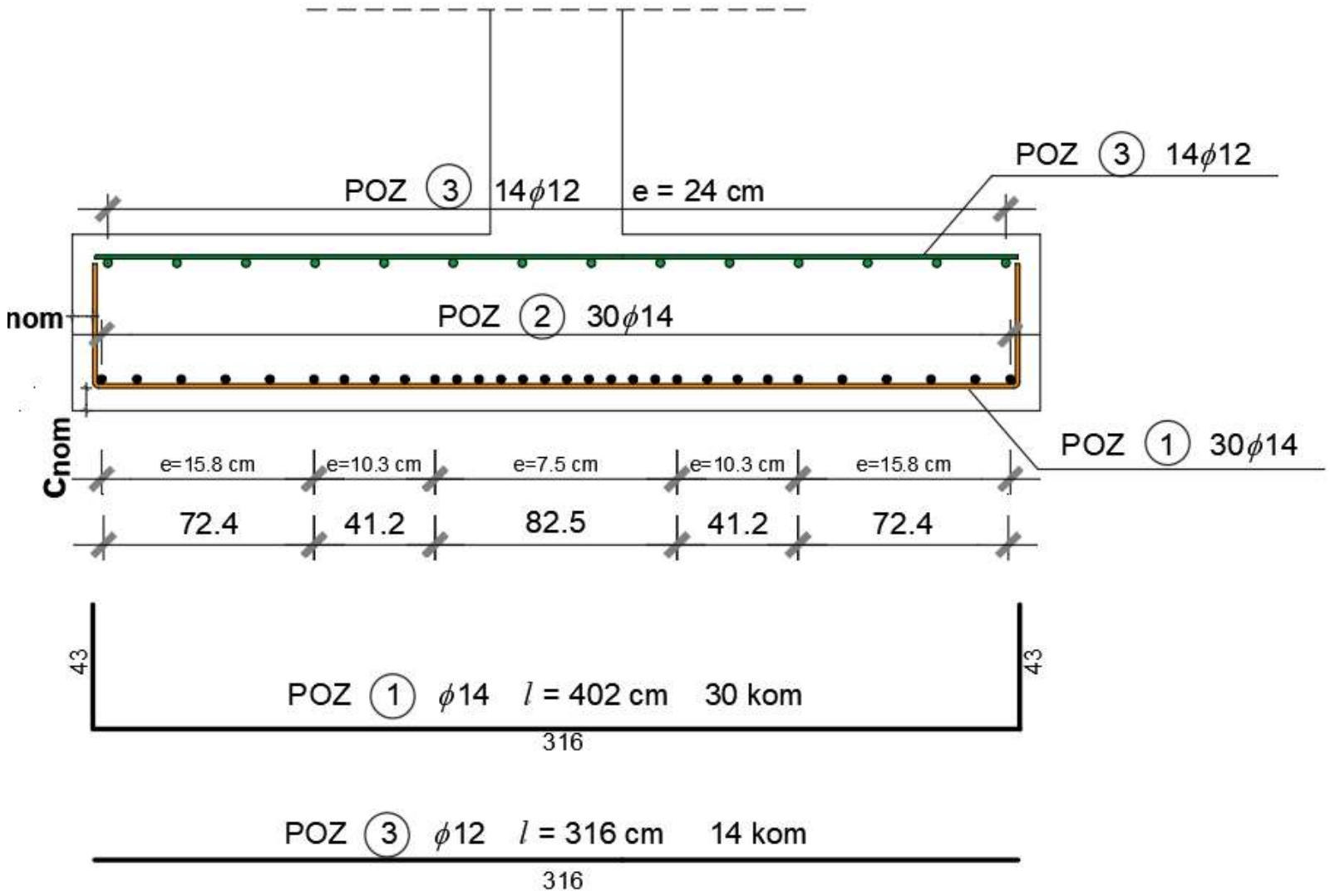


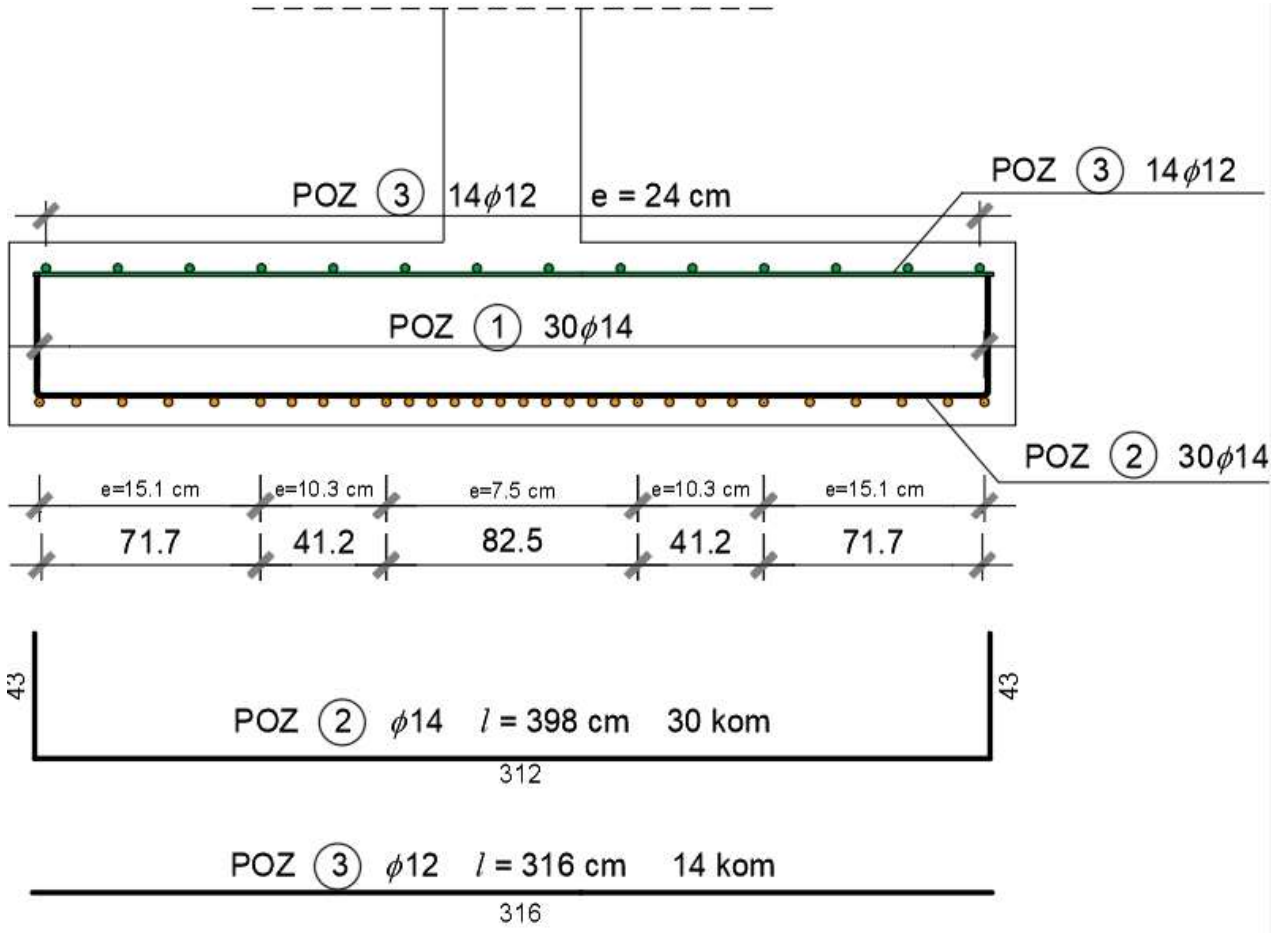


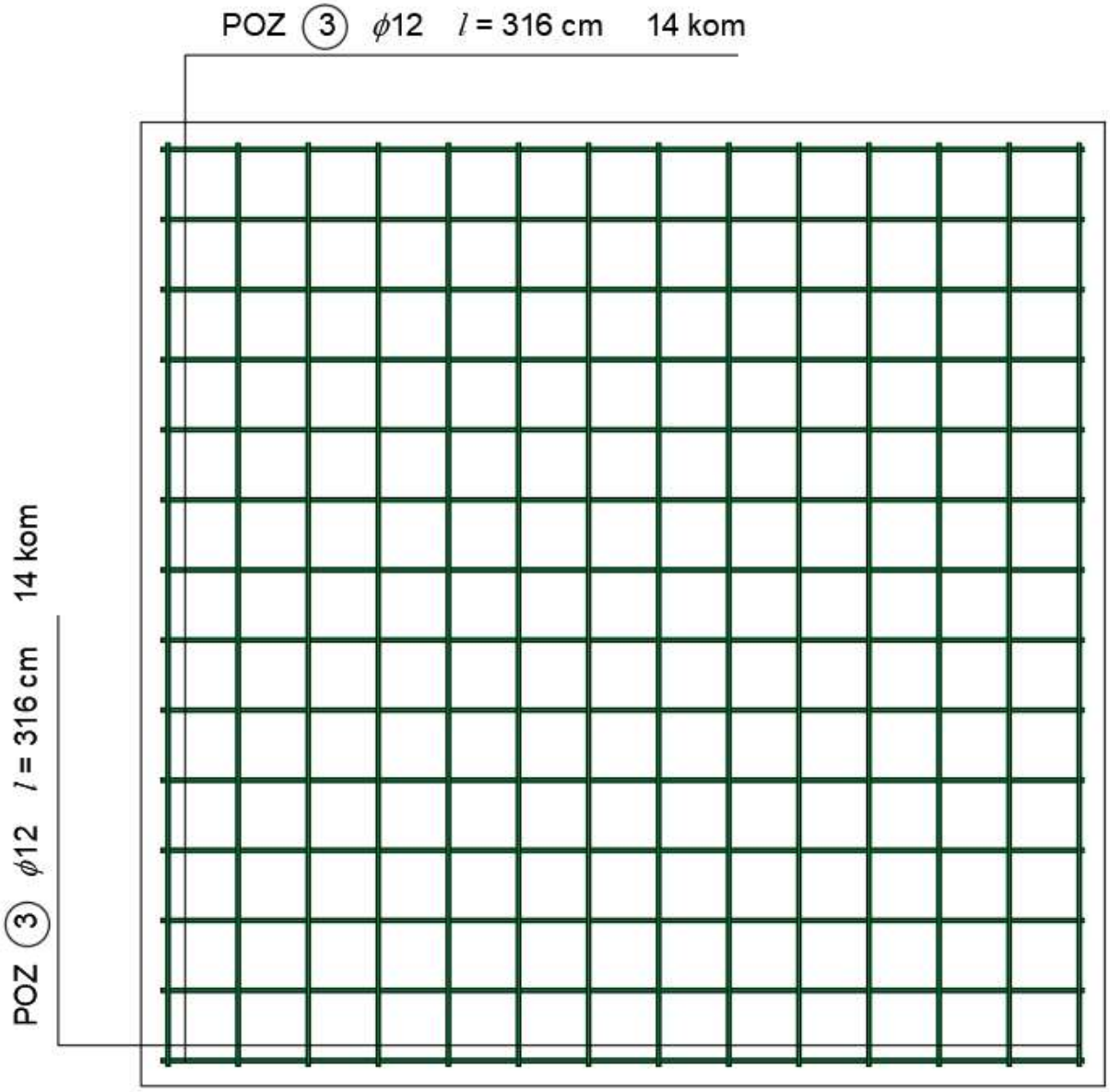


Plan armature donja zona

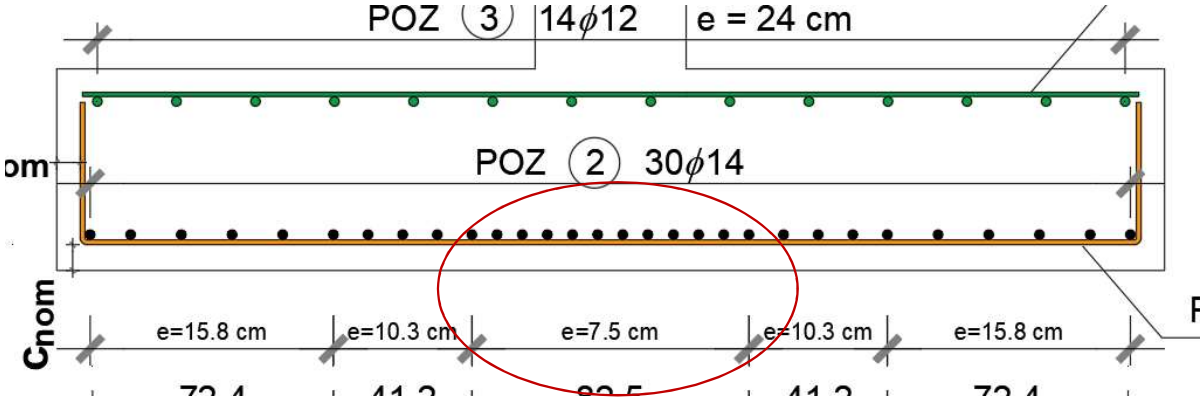

3φ14 3φ14 4φ14 6φ14 6φ14 4φ14 3φ14 3φ14
3φ14 3φ14 4φ14 6φ14 6φ14 4φ14 3φ14 3φ14
POZ ③ 14φ12
POZ ② 30φ14
e = 24 cm
POZ ① 30φ14
POZ ③ 14φ12
71.7
41.2
82.5
41.2
71.7
POZ ② φ14 l = 398 cm 30 kom
POZ ③ φ12 l = 316 cm 14 kom
POZ ③ 14φ12
e = 24 cm
POZ ③ 14φ12
Cnom
POZ ② 30φ14
Cnom
POZ ① 30φ14
72.4
41.2
82.5
41.2
72.4
POZ ① φ14 l = 402 cm 30 kom
POZ ③ φ12 l = 316 cm 14 kom


POZ 3 14ϕ12
e = 24 cm
POZ 3 14ϕ12
POZ 2 30ϕ14
nom
POZ 1 30ϕ14
cnom
e=15.8 cm
e=10.3 cm
e=7.5 cm
e=10.3 cm
e=15.8 cm
72.4
41.2
82.5
41.2
72.4
43
43
POZ 1 ϕ14 l = 402 cm 30 kom
316
POZ 3 ϕ12 l = 316 cm 14 kom
316


POZ ③ 14ϕ12
e = 24 cm
POZ ③ 14ϕ12
POZ ① 30ϕ14
POZ ② 30ϕ14
e=15.1 cm
e=10.3 cm
e=7.5 cm
e=10.3 cm
e=15.1 cm
71.7
41.2
82.5
41.2
71.7
43
43
POZ ② ϕ14 l = 398 cm 30 kom
312
POZ ③ ϕ12 l = 316 cm 14 kom
316


POZ ③ ϕ12 l = 316 cm 14 kom
POZ ③ ϕ12 l = 316 cm 14 kom

Minimalni razmaci armature



$$e_{min} = \{k_1 \cdot \phi;\ d_g + k_2; 20\ mm\}$$

$k_1 = 1$

$k_2 = 5\ mm$

d_g najveće zrno agregata

$$e = 7.5\ -\ \frac{1.4}{2} - \frac{1.4}{2} = 6.1\ cm < e_{min} = \{1 \cdot 2.4;\ \ 2.4 + 0.5;\ \ 2\}$$

Proračun na proboj

Kombinacija	V_{Ed}	$M_{Ed,y}$	$M_{Ed,z}$	$H_{Ed,y}$	$H_{Ed,z}$
Osnovna	1368.02	284.25	354.75	0.00	0.00
Seizmička	983.35	579.30	440.50	110.00	68.00

Stranica 13

$$V_{Ed} = 1368.02\ kN$$

$$V_{A,Ed} = 983.35\ kN$$

$$d = \frac{d_y + d_z}{2} = \frac{52.3 + 50.9}{2} = 51.6\ cm$$

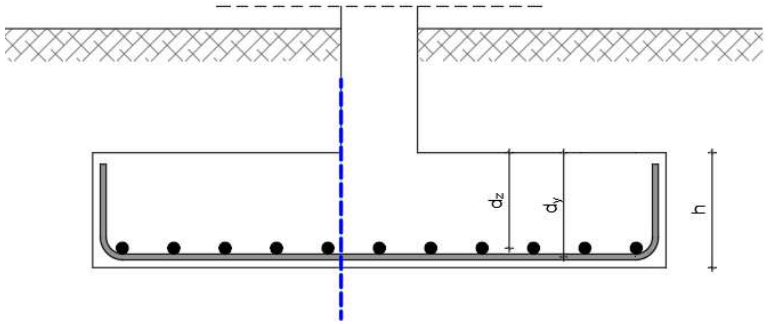
Stranica 10

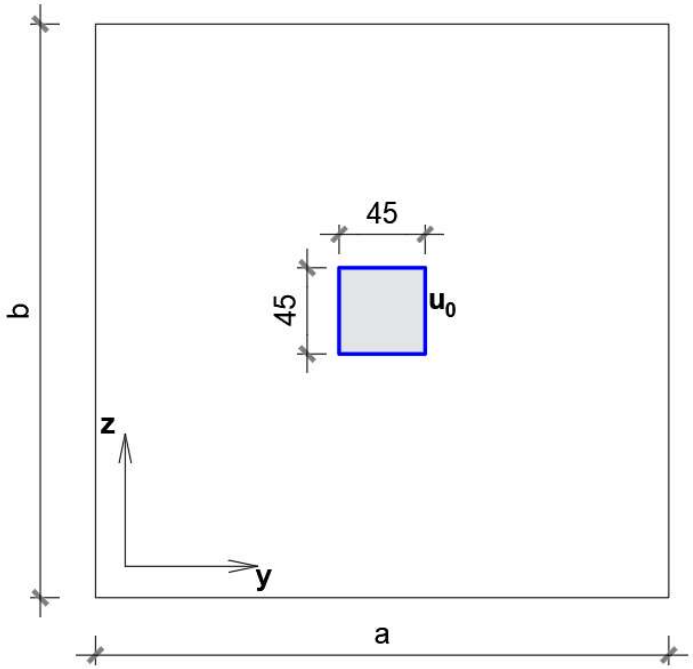
$$\rho_y = \frac{2 \cdot (4.62 + 4.62 + 6.16 + 7.70)}{330 \cdot 52.3} = 0.00267\ cm^2$$

$$\rho_z = \frac{2 \cdot (4.62 + 4.62 + 6.16 + 7.70)}{330 \cdot 50.9} = 0.00275\ cm^2$$

$$\rho = \sqrt{\rho_y \cdot \rho_z} = \sqrt{0.00267 \cdot 0.00275} = 0.0085 \leq 0.02$$

Kontrola naprezanja uz lice stupa





$$v_{Ed,0} = \beta \cdot \frac{V_{Ed}}{u_0 \cdot d}$$ Stranica 30, lekcija 7

$u_0 = 2 \cdot (c_1 + c_2) = 2 \cdot (45 + 45) = 180\ cm$

$d = 51.6\ cm$

$\beta = ?$ Stranica 32, lekcija 7

NAPOMENA: <u>samo</u> za proboj kroz temelj smije se umanjiti sila proboja. U ovom primjeru neće se umanjivati.

$$V_{Ed,red} = V_{Ed} - \Delta V_{Ed}; \quad \Delta V_{Ed} = q_{Ed} \cdot A_{cont}$$

Kontrola naprezanja uz lice stupa (stranica 30, uvjet 1)

Za ekscentricitet oko obje osi srednjega stupa, koeficijent β računa se prema izrazu (stranica 34, lekcija 7):

$$\beta = 1 + 1.8 \cdot \sqrt{\left(\frac{e_y}{b_z}\right)^2 + \left(\frac{e_z}{b_y}\right)^2}$$

b_z, b_y dimenzije kontrolnog opsega – ovdje su to dimenzije stupa (stranica 26, lekcija 7)

$$\beta = 1 + 1.8 \cdot \sqrt{\left(\frac{25.93}{45}\right)^2 + \left(\frac{20.77}{45}\right)^2} = 2.33$$

$$\nu_{Ed,0} = 2.33 \cdot \frac{1368020}{1800 \cdot 516} = 3.43\ N/mm^2$$

$$\nu_{Rd,max} = 0.4 \cdot 0.6 \left[1 - \frac{f_{ck}}{250}\right] \cdot f_{cd}$$ (stranica 31, lekcija 7)

$$\nu_{Rd,max} = 0.4 \cdot 0.6 \left[1 - \frac{25}{250}\right] \cdot 16.67 = 3.60\ N/mm^2$$

$$\nu_{Ed,0} \leq \nu_{Rd,max}$$ 

Otpornost na posmični proboj (stranica 30, uvjeti 2 i 3)

$$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{\frac{1}{3}} + k_1 \cdot \sigma_{cp} \geq v_{min} + k_1 \cdot \sigma_{cp}$$ stranica 31, lekcija 7

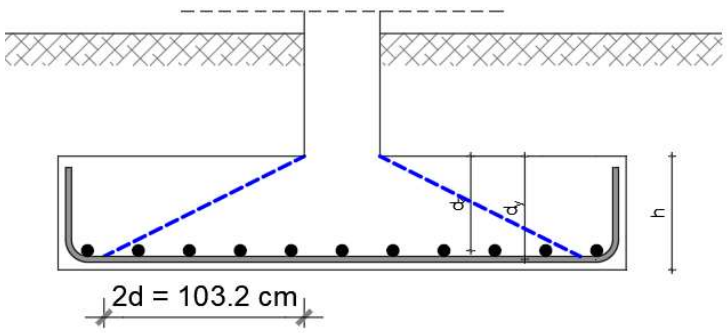
$$C_{Rd,c} = \frac{0.18}{1.5} = 0.12 \qquad k = 1 + \sqrt{\frac{200}{516}} = 1.62 \leq 2.0 \qquad k_1 = 0.1$$

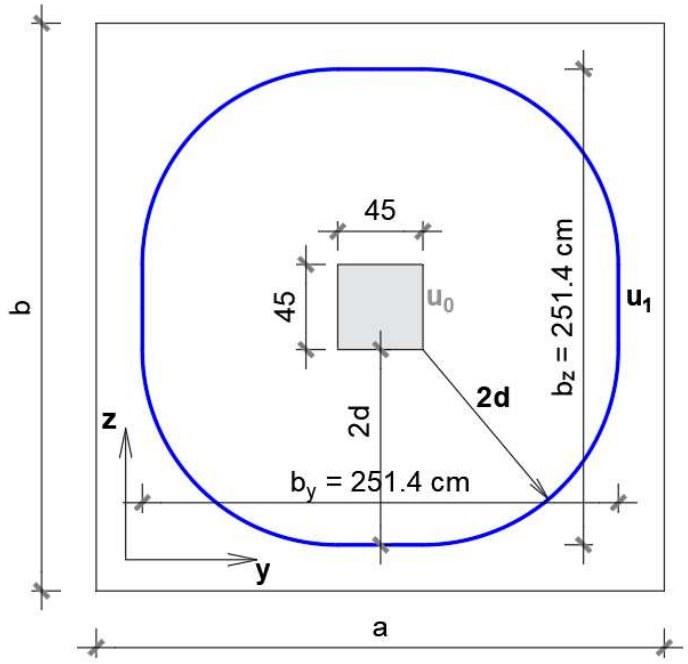
$$\rho = \sqrt{\rho_y \cdot \rho_z} = \sqrt{0.00267 \cdot 0.00275} = 0.0085 \leq 0.02 \qquad v_{min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}^{\frac{1}{2}} = 0.035 \cdot 1.62^{\frac{3}{2}} \cdot 25^{\frac{1}{2}} = 0.3608$$

$$v_{Rd,c} = 0.12 \cdot 1.62 \cdot (100 \cdot 0.0085 \cdot 25)^{\frac{1}{3}} + 0.1 \cdot 0 \geq 0.3608 + 0.1 \cdot 0$$

$$v_{Rd,c} = 0.538\ N/mm^2 \geq v_{min} = 0.3608\ N/mm^2$$ 

Naprezanje na prvom kontrolnom opsegu





$$v_{Ed,1} = \beta \cdot \frac{V_{Ed}}{u_1 \cdot d}$$

$$\beta = 1 + 1.8 \cdot \sqrt{\left(\frac{e_y}{b_z}\right)^2 + \left(\frac{e_z}{b_y}\right)^2}$$

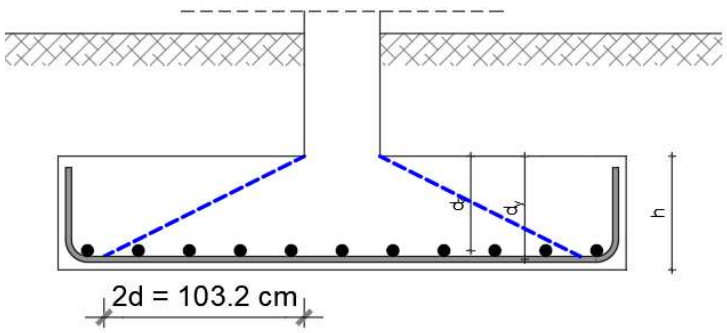
$$\beta = 1 + 1.8 \cdot \sqrt{\left(\frac{25.93}{251.4}\right)^2 + \left(\frac{20.77}{251.4}\right)^2} = 1.24$$

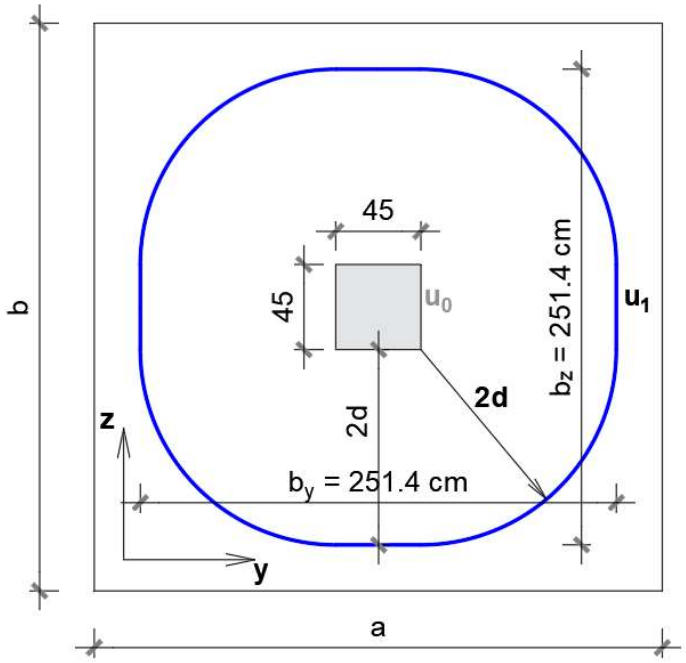
$$u_1 = 2 \cdot (c_1 + c_2) + 2 \cdot (2 \cdot d) \cdot \pi = 2 \cdot 90 + 2 \cdot 103.2 \cdot \pi = 828.09\ cm$$

$$v_{Ed,1} = 1.24 \cdot \frac{1368020}{8280.9 \cdot 516} = 0.396\ N/mm^2$$

$$v_{Ed,1} = 0.396\ N/mm^2 \leq v_{Rd,c} = 0.538\ N/mm^2$$

Naprezanje na prvom kontrolnom opsegu





$$v_{Ed,1} = \beta \cdot \frac{V_{Ed}}{u_1 \cdot d}$$

$$\beta = 1 + 1.8 \cdot \sqrt{\left(\frac{e_y}{b_z}\right)^2 + \left(\frac{e_z}{b_y}\right)^2}$$

$$\beta = 1 + 1.8 \cdot \sqrt{\left(\frac{25.93}{251.4}\right)^2 + \left(\frac{20.77}{251.4}\right)^2} = 1.24$$

$$u_1 = 2 \cdot (c_1 + c_2) + 2 \cdot (2 \cdot d) \cdot \pi = 2 \cdot 90 + 2 \cdot 103.2 \cdot \pi = 828.09\ cm$$

$$v_{Ed,1} = 1.24 \cdot \frac{1368020}{8280.9 \cdot 516} = 0.396\ N/mm^2$$

$$v_{Ed,1} = 0.396\ N/mm^2 \leq v_{Rd,c} = 0.538\ N/mm^2$$