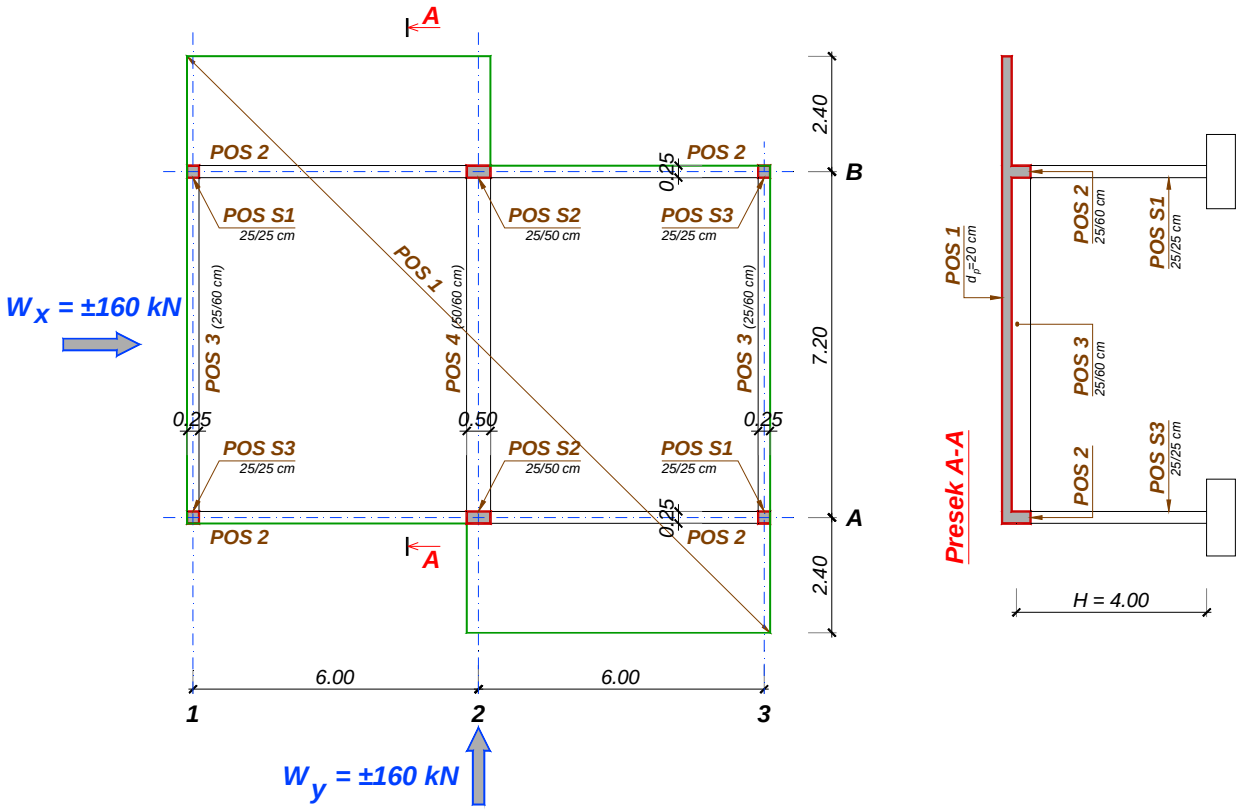
04 *Konstrukcija prikazana na skici je, pored sopstvene težine, opterećena i jednako raspodeljenim povremenim opterećenjem* ***p = 10 kN/m²****, koje može delovati u proizvoljnom položaju na ploči. Dejstvo vetra je predstavljeno ukupnim horizontalnim silama W = ±160 kN u dva ortogonalna pravca. Potrebno je:*

1. *Dimenzionisati u karakterističnim presecima ploču* ***POS 1*** *(d_p = 20 cm). Usvojeni raspored armature prikazati u osnovi, posebno za gornju i donju zonu.*



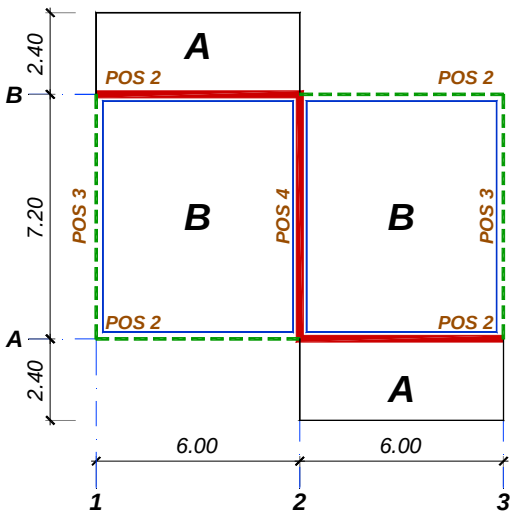
2. *Izvršiti analizu opterećenja, sračunati statičke uticaje i dimenzionisati* ***POS 2, POS 3*** *(b/d = 25/60 cm) i* ***POS 4*** *(b/d = 50/60 cm). Grede je potrebno dimenzionisati za najnepovoljnije položaje povremenog opterećenja, ne uzimajući u obzir uticaj vetra.*
3. *Skicirati plan armature grede* ***POS 2*** *u približnoj razmeri.*
4. *Dimenzionisati stubove* ***POS S2*** *(25/50 cm), odnosno* ***POS S1*** *i* ***S3*** *(25/25 cm, armirati istom armaturom, prema merodavnim uticajima). Uticaj izvijanja zanemariti.*

   Kvalitet materijala: ***MB 30 , RA 400/500***

1. POS 1 – ploča d_p = 20 cm

Ploča se sastoji od konzolnih prepusta (delovi »A«) i krstastih ploča dimenzija 7,2×6,0 m (delovi »B«).

$g = 0.20 \times 25 = 5.0$ kN/m² ; $p = 10.0$ kN/m²



a. Konzolna ploča L=2.4 m

$R_g = 5.0 \times 2.4 = 12.0$ kN/m

$R_p = 10.0 \times 2.4 = 24.0$ kN/m

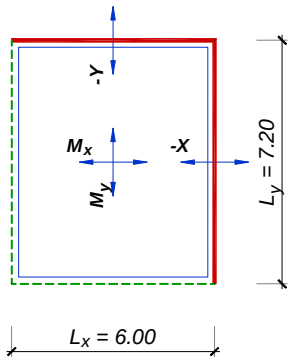
$q_u = 1.6 \times 5.0 + 1.8 \times 10.0 = 26.0$ kN/m²

$M_u = 26.0 \times 2.4^2/2 = 74.88$ kNm/m

b. Krstasta ploča

Kako se povremeno opterećenje može naći u proizvoljnom položaju na konstrukciji, potrebno ga je razdvojiti na simetrični deo p/2 (deluje po čitavoj površini ploče) i antimetrični deo ±p/2 (razlikuje se u zavisnosti od razmatranog uticaja).

Simetrični deo (g,p/2)



$L_y/L_x = 7.2/6.0 = 1.2$

$G = P/2 = 5.0 \times 6.0 \times 7.2 = 216\ kN$

$Q_{u1} = 1.6 \times G + 1.8 \times P/2 = 734.4\ kN$

$M_{xu1} = 0.032 \times 734.4 = 23.5\ kNm/m$

$M_{yu1} = 0.023 \times 734.4 = 16.9\ kNm/m$

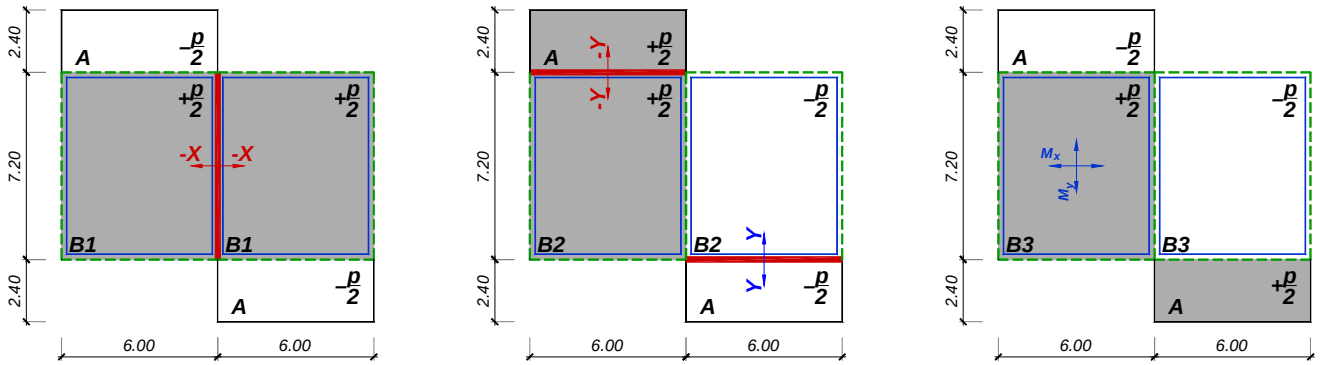
$-X_{u1} = 0.071 \times 734.4 = 52.1\ kNm/m$

$-Y_{u1} = 0.062 \times 734.4 = 45.5\ kNm/m$

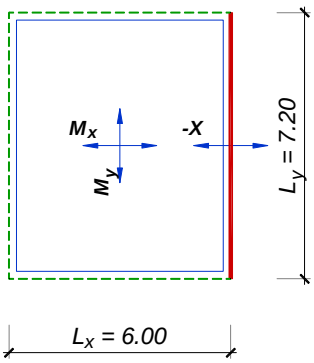
Antimetrični deo (±p/2)

$P/2 = 5.0 \times 6.0 \times 7.2 = 216\ kN \quad \Rightarrow \quad Q_{u2} = \pm 1.8 \times P/2 = \pm 1.8 \times 216 = \pm 388.8\ kN$

Šeme povremenog opterećenja koje daju najveće momente nad osloncima i u poljima su prikazane na narednoj skici. Pri tome se srednja šema (maksimalni momenti –Y) neće ni razmatrati, s obzirom da se na spoju konzolne i krstaste ploče uvek usvaja moment sa konzole.



Maksimalni oslonački moment -X



$-X_{u2} = k^{B1} \times Q_{u2} = 0.082 \times Q_{u2}$

$-X_{u2} = 0.082 \times 388.8 = 31.9\ kNm/m$

$-X_u = (-X)_{u1} + (-X)_{u2} = 52.1 + 31.9 = 84.0\ kNm/m$

$pretp.\ a_{1x} = 3.0\ cm \quad \Rightarrow \quad h_x = d - a_1 = 20 - 3 = 17\ cm$

$$k = \frac{17}{\sqrt{\frac{84.0}{2.05}}} = 2.655 \Rightarrow \begin{matrix} \varepsilon_b / \varepsilon_a = 2.615 / 10‰ \\ \bar{\mu} = 15.444\% \\ \zeta = 0.918 \end{matrix}$$

$$A_a = 15.444 \times 17 \times \frac{2.05}{40} = 13.46\ \frac{cm^2}{m} \quad \Rightarrow \quad usv.: \quad \textbf{RØ16/15}\ (13.40\ cm^2/m)$$

$A_{ap} = 0.2 \times 13.46 = 2.69\ cm^2/m \quad \Rightarrow \quad usv.: \quad \textbf{RØ10/25}\ (3.14\ cm^2/m)$

Maksimalni oslonački moment -Y

$-Y_u = 74.88$ kNm/m (moment sa konzolne ploče)

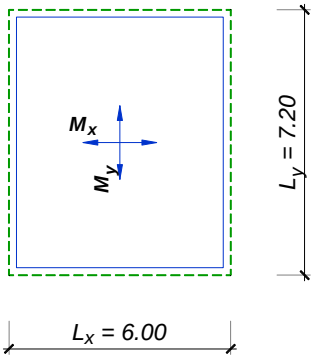
$a_{1y} = 2.0 + 1.6 + 1.6/2 = 4.4$ cm $\Rightarrow$ $h_y = 20 - 4.4 = 15.6$ cm

$$k = \frac{15.6}{\sqrt{\frac{74.88}{2.05}}} = 2.581 \Rightarrow \begin{matrix} \varepsilon_b / \varepsilon_a = 2.763/10‰ \\ \bar{\mu} = 16.427\% \\ \zeta = 0.914 \end{matrix}$$

$$A_a = 16.427 \times 15.6 \times \frac{2.05}{40} = 13.13 \frac{cm^2}{m} \Rightarrow \text{usv.: } \textbf{RØ16/15} \ (13.40\ cm^2/m)$$

$A_{ap} = 0.2 \times 13.13 = 2.63\ cm^2/m$ $\Rightarrow$ usv.: **RØ10/25** $(3.14\ cm^2/m)$

Maksimalni momenti u polju M_x, M_y



$M_{xu2} = k^{B3} \times Q_{u2} = 0.049 \times Q_{u2}$

$M_{xu2} = 0.049 \times 388.8 = 19.1$ kNm/m

$M_{xu} = M_{xu1} + M_{xu2} = 23.5 + 19.1 = 42.6$ kNm/m

$M_{yu2} = k^{B3} \times Q_{u2} = 0.038 \times Q_{u2}$

$M_{yu2} = 0.038 \times 388.8 = 14.8$ kNm/m

$M_{yu} = M_{yu1} + M_{yu2} = 16.9 + 14.8 = 31.7$ kNm/m

$a_{1x} = 2.0 + 1.2/2 = 2.6$ cm $\Rightarrow$ $h_x = 20 - 2.6 = 17.4$ cm

$$A_{ax} \approx \frac{42.6 \times 10^2}{0.9 \times 17.4 \times 40} = 6.79 \frac{cm^2}{m} \Rightarrow \text{usv.: } \textbf{RØ12/15} \ (7.54\ cm^2/m)$$

$a_{1y} = 2.0 + 1.2 + 1.0/2 = 3.7$ cm $\Rightarrow$ $h_y = 20 - 3.7 = 16.3$ cm

$$A_{ay} \approx \frac{31.7 \times 10^2}{0.9 \times 16.3 \times 40} = 5.40 \frac{cm^2}{m} \Rightarrow \text{usv.: } \textbf{RØ10/15} \ (5.24\ cm^2/m)$$

Za usvojenu armaturu moguće je dokazati moment nosivosti:

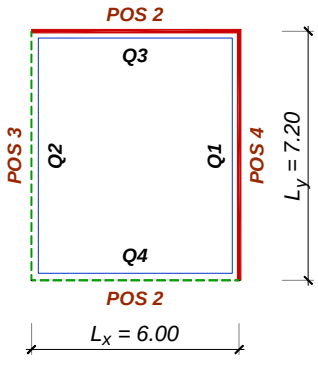
$$\bar{\mu} = \frac{A_a \times \sigma_v}{b \times h \times f_B} = \frac{5.24 \times 40}{100 \times 16.3 \times 2.05} = 6.268\% \Rightarrow k = 4.082$$

$$M_u = \left(\frac{16.3}{4.082} \right)^2 \times 2.05 = 32.68 \frac{kNm}{m} > 31.7 \frac{kNm}{m} = M_{yu}$$

2. Analiza opterećenja za grede

Simetrični deo (g,p/2)

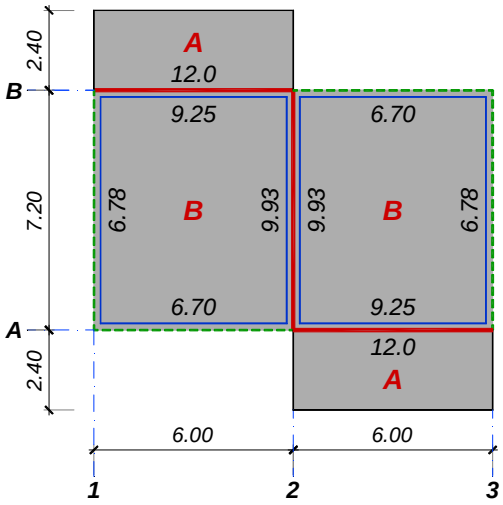
$G = P/2 = 5.0 \times 6.0 \times 7.2 = 216$ kN



greda	k		G = P/2 kN	L m	g = p1 kN/m
POS 4	0.331	**Q_1**	71.5	7.2	**9.93**
POS 3	0.226	**Q_2**	48.8	7.2	**6.78**
POS 2	0.257	**Q_3**	55.5	6.0	**9.252**
POS 2	0.186	**Q_4**	40.2	6.0	**6.696**

Opterećenje sa konzolnih prepusta:

$$R_g = R_{p/2} = 5.0 \times 2.4 = 12.0 \text{ kN/m}$$



Opterećenje na grede usled stalnog, odnosno simetričnog dela povremenog opterećenja prikazan je na skici desno. Antimetrični deo opterećenja će biti prikazan posebno za svaku gredu (uticaj i deo nosača koji se razmatra).

Pored ovog opterećenja, potrebno je stalnom opterećenju dodati sopstvenu težinu:

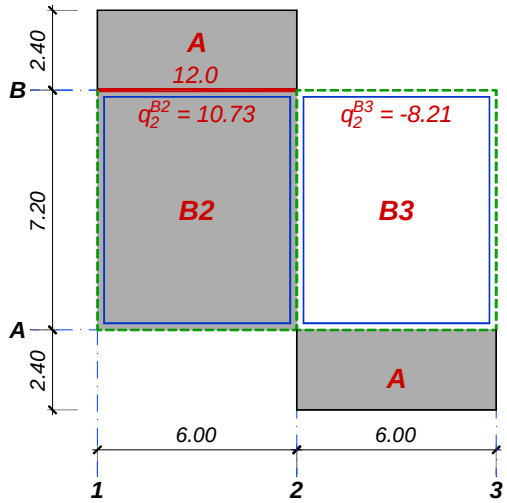
$$g_{g2} = g_{g3} = 0.25 \times 0.60 \times 25 = 3.75 \text{ kN/m}$$

$$g_{g4} = 0.50 \times 0.60 \times 25 = 7.50 \text{ kN/m}$$

3. Proračun grede POS 2

Presek u prvom polju

Merodavan položaj povremenog opterećenja je prikazan na skici desno. Potrebno je aplicirati maksimalno moguće opterećenje u prvo, a minimalno moguće (maksimalno negativno) opterećenje u drugo polje.



U osenčenim poljima deluje opterećenje +p/2 a u neosenčenim –p/2, što čini, u kombinaciji sa simetričnim delom opterećenja +p/2, da su osenčena polja opterećena, a neosenčena neopterećena povremenim opterećenjem p.

$$Q = 6.0 \times 7.2 \times 10.0/2 = 216 \text{ kN}$$

$$Q_2^{B2} = 0.298 \times 216 = 64.4 \text{ kN}$$

$$q_2^{B2} = \frac{64.4}{6.0} = 10.73 \frac{\text{kN}}{\text{m}}$$

$$Q_2^{B3} = -0.228 \times 216 = 49.2 \text{ kN} \Rightarrow q_2^{B3} = -\frac{49.2}{6.0} = -8.21 \frac{\text{kN}}{\text{m}}$$

$$g_1 = 3.75 + 12.0 + 9.25 = 25.0 \text{ kN/m}$$

$$g_2 = 3.75 + 6.70 = 10.45 \text{ kN/m}$$

$$A_g = \left(\frac{7}{16} g_1 - \frac{1}{16} g_2\right) \times L = \frac{7 \times 25.0 - 10.45}{16} \times 6.0 = 61.7 \text{ kN}$$

$$C_g = \left(\frac{7}{16} g_2 - \frac{1}{16} g_1\right) \times L = \frac{7 \times 10.45 - 25.0}{16} \times 6.0 = 18.0 \text{ kN}$$

$$B_g = \left(\frac{5}{8} g_1 + \frac{5}{8} g_2\right) \times L = \frac{5 \times (25.0 + 10.45)}{8} \times 6.0 = 132.9 \text{ kN}$$

$$p_1 = 12.0 + 9.25 + 12.0 + 10.73 = 43.98 \text{ kN/m}$$

$$p_2 = 6.70 + (-8.21) = -1.51 \text{ kN/m}$$

Pri ovom položaju povremenog opterećenja javljaju se maksimalna reakcija A_p, minimalna reakcija C_p, kao i maksimalna transverzalna sila uz oslonac A:

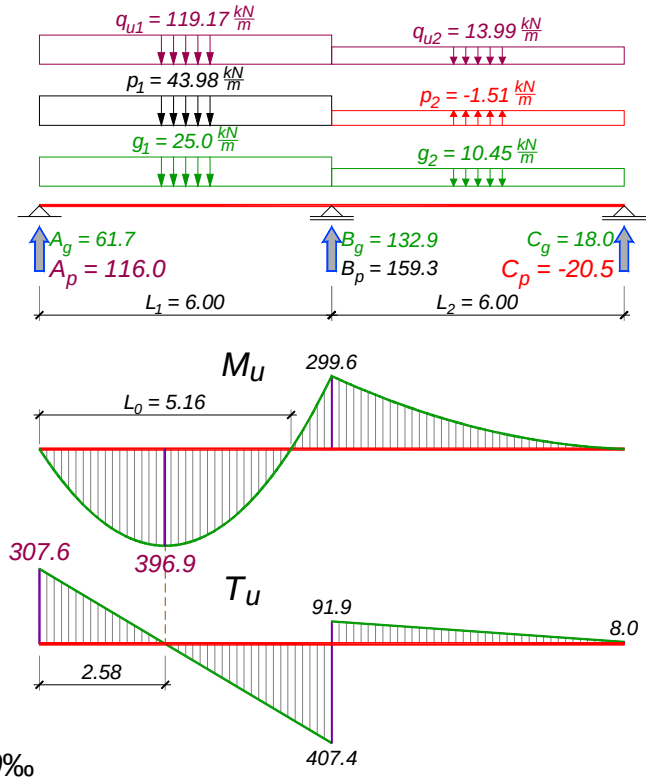
$$A_{p,\max} = \frac{7\times 43.98 - (-1.51)}{16}\times 6.0 = 116.0\,kN$$

$$C_{p,\min} = \frac{7\times(-1.51) - 43.98}{16}\times 6.0 = -20.5\,kN$$

$q_{u1} = 1.6\times25.0 + 1.8\times43.98 = 119.17$ kN/m

$q_{u2} = 1.6\times10.45 + 1.8\times(-1.51) = 13.99$ kN/m

$A_u = 1.6\times61.7 + 1.8\times116.0 = 307.6$ kN



$$x_{\max} = \frac{307.6}{119.17} = 2.58\,m$$

$$M_{u,\max} = \frac{307.6^2}{2\times119.17} = 396.9\,kNm$$

$$B = \min\begin{Bmatrix} 25 + \frac{516}{4} = 154 \\ 25 + 20\times20 = 425 \end{Bmatrix} = 154\,cm$$

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

$$k = \frac{53}{\sqrt{\frac{396.9\times10^2}{154\times2.05}}} = 4.728 \Rightarrow \begin{matrix} \varepsilon_b / \varepsilon_a = 1.128/10‰ \\ s = 0.101 \Rightarrow x = 0.101\times53 = 5.4\,cm < d_p = 20\,cm \\ \bar{\mu} = 4.640\% \end{matrix}$$

$$A_a = 4.640\times\frac{154\times53}{100}\times\frac{2.05}{40} = 19.42\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{6RØ22}\ (22.81\ cm^2)$$

$$\tau_n = \frac{307.6}{25\times0.9\times53} = 0.258\,\frac{kN}{cm^2} \quad \begin{cases} > \tau_r = 1.1\,MPa \\ < 3\tau_r \end{cases}$$

$$\lambda = 2.58\times\left(1 - \frac{0.11}{0.258}\right) = 1.48\,m \quad ; \quad \tau_{Ru}^A = \frac{3}{2}\times(0.258 - 0.11) = 0.222\,\frac{kN}{cm^2}$$

$$e_u = \frac{2\times0.785}{25\times0.222}\times40 = 11.3\ cm \quad \Rightarrow \quad \text{usvojeno } \mathbf{URØ10/10}\ (m=2)$$

$$\Delta A_a = \frac{307.6}{2\times40}\times(\cot 45° - \cot 90°) = 3.84\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{2RØ22}\ (7.60\ cm^2)$$

Presek u drugom polju

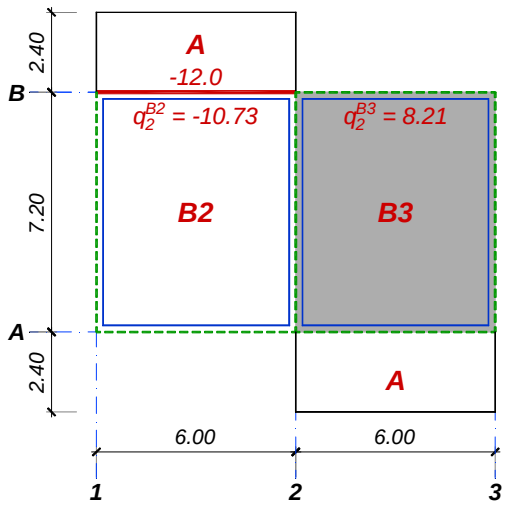
Merodavan položaj povremenog opterećenja je prikazan na skici desno. Potrebno je aplicirati maksimalno moguće opterećenje u drugo, a minimalno moguće (maksimalno negativno) opterećenje u prvo polje.

U odnosu na prethodni razmotreni slučaj (prvo polje), položaj opterećenja je isti a znaci suprotni, pa sledi:

$p_1 = 12.0 + 9.25 - 12.0 - 10.73 = -1.48$ kN/m

$p_2 = 6.70 + 8.21 = 14.91$ kN/m

Veličina stalnog opterećenja se, naravno, ne menja.



Pri ovom položaju povremenog opterećenja javljaju se maksimalna reakcija C_p, minimalna reakcija A_p, kao i maksimalna transverzalna sila uz oslonac C:

$$A_{p,\min} = \frac{7\times(-1.48)-14.91}{16}\times 6.0 = -9.5\,kN$$

$$C_{p,\max} = \frac{7\times 14.91-(-1.48)}{16}\times 6.0 = 39.7\,kN$$

$q_{u1} = 1.6\times 25.0 + 1.8\times(-1.48) = 37.35$ kN/m

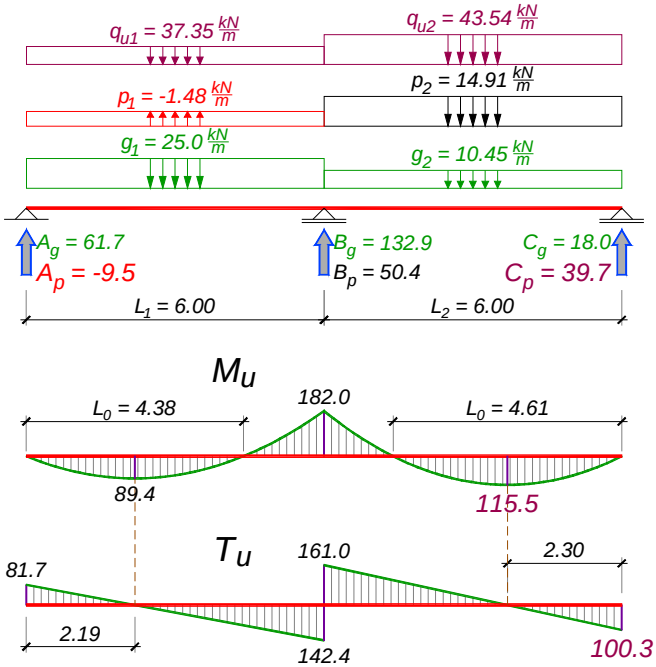
$q_{u2} = 1.6\times 10.45 + 1.8\times 14.91 = 43.54$ kN/m

$C_u = 1.6\times 18.0 + 1.8\times 39.7 = 100.3$ kN

$$x_{\max} = \frac{100.3}{43.54} = 2.30\,m$$

$$M_{u,\max} = \frac{100.3^2}{2\times 43.54} = 115.5\,kNm$$

$$B = \min\begin{Bmatrix} 25+\frac{461}{12}=63 \\ 25+8\times 20 = 185 \end{Bmatrix} = 63\,cm$$



$a_1 = 4.5$ cm $\Rightarrow$ $h = 60 - 4.5 = 55.5$ cm

$$k = \frac{55.5}{\sqrt{\frac{115.5\times 10^2}{63\times 2.05}}} = 5.887 \Rightarrow \begin{matrix} \varepsilon_b/\varepsilon_a = 0.869/10‰ \\ s = 0.080 \Rightarrow x = 0.080\times 55.5 = 4.4\,cm < d_p = 20\,cm \\ \bar{\mu} = 2.968\% \end{matrix}$$

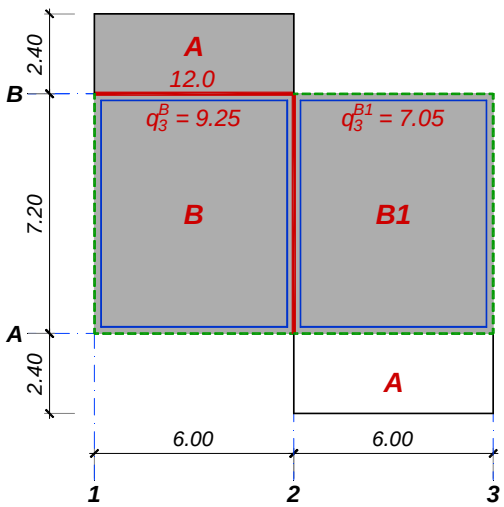
$$A_a = 2.968\times\frac{63\times 55.5}{100}\times\frac{2.05}{40} = 5.35\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{3RØ16}\ (6.03\,cm^2)$$

Kontrola glavnih napona zatezanja

$$\tau_n = \frac{100.3}{25\times 0.9\times 53} = 0.054\,\frac{kN}{cm^2} < \tau_r \quad \Rightarrow \quad \text{usvojeno } \mathbf{URØ8/30\ (15)}$$

Presek nad osloncem

Merodavan položaj povremenog opterećenja je prikazan na skici desno (maksimalno moguće opterećenje u oba raspona). U osenčenim poljima deluje opterećenje +p/2 a u neosenčenom polju –p/2.



$Q = 6.0\times 7.2\times 10.0/2 = 216$ kN

$$q_3^B = \frac{0.257\times 216}{6.0} = 9.25\,\frac{kN}{m}$$

$$Q_3^{B1} = 0.196\times 216 = 42.3\,kN$$

$$q_3^{B1} = \frac{42.3}{6.0} = 7.05\,\frac{kN}{m}$$

$p_1 = 12.0 + 9.25 + 12.0 + 9.25 = 42.50$ kN/m

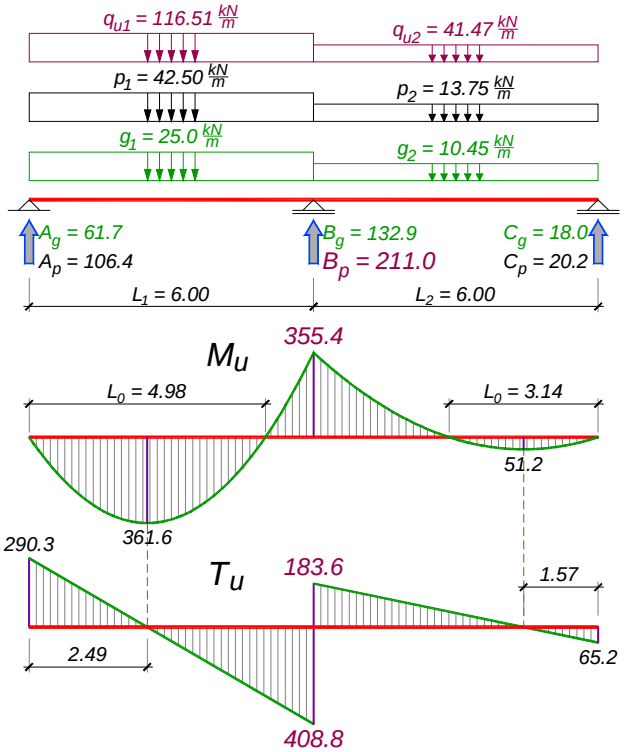
$p_2 = 6.70 + 7.05 = 13.75$ kN/m

Pri ovom položaju povremenog opterećenja javljaju se maksimalna reakcija B_p, kao i maksimalne transverzalne sile uz oslonac B:

$$A_p = \frac{7\times 42.50 - 13.75}{16}\times 6.0 = 106.4\,kN$$

$$C_p = \frac{7\times 13.75 - 42.50}{16}\times 6.0 = 20.2\,kN$$

$$B_{p,\max} = \frac{5\times(42.5+13.75)}{8}\times 6.0 = 211.0\,kN$$



$q_{u1} = 1.6\times 25.0 + 1.8\times 42.50 = 116.51$ kN/m

$q_{u2} = 1.6\times 10.45 + 1.8\times 13.75 = 41.47$ kN/m

$$M_{u,\max} = -\left(\frac{q_1 L_1^2}{16} + \frac{q_2 L_2^2}{16}\right)$$

$$M_{u,\max} = -\frac{116.51 + 41.47}{16}\times 6.0^2 = -355.4\,kNm$$

Zategnuta je gornja ivica, pa se presek dimenzioniše kao pravougaoni, širine b = 25 cm:

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

$$k = \frac{53}{\sqrt{\frac{355.4\times 10^2}{25\times 2.05}}} = 2.012 \Rightarrow \varepsilon_b / \varepsilon_a = 3.5 / 6.264‰,\quad \bar{\mu} = 29.017\%$$

$$A_a = 29.017\times\frac{25\times 53}{100}\times\frac{2.05}{40} = 19.70\,cm^2 \Rightarrow \text{usvojeno } \mathbf{6RØ22}\ (22.81\ cm^2)$$

Kontrola glavnih napona zatezanja

Presek B^{levo}

$A_u = 1.6\times 61.7 + 1.8\times 106.4 = 290.3$ kN

$$T_u^{B,l} = A_u - q_{u1}L_1 = 290.3 - 116.51\times 6.0 = -408.8\,kN$$

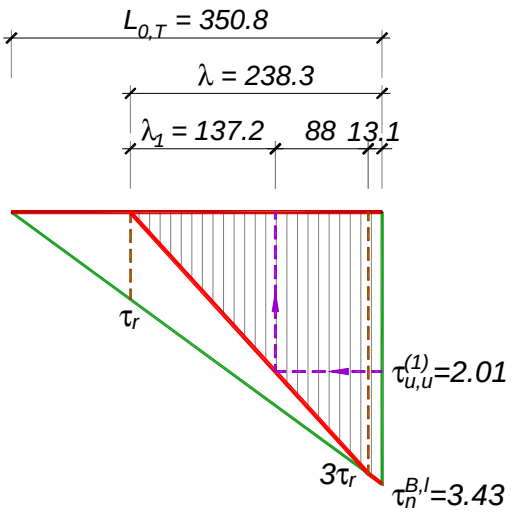
$$\tau_n^{B'l} = \frac{408.8}{25\times 0.9\times 53} = 0.343\,\frac{kN}{cm^2} > 3\tau_r$$

$L_{0,T} = 6.0 - 2.49 = 3.51$ m

$$\lambda = 3.51\times\left(1 - \frac{0.11}{0.343}\right) = 2.38\,m$$

$$e_u = \frac{2\times 0.785}{25\times 0.343}\times 40 = 7.33\ cm$$

usvojeno **2URØ10/12.5**



Dužina na kojoj je prekoračen napon $3\tau_r$ je:

$$x = 3.51\times\left(1 - \frac{0.33}{0.343}\right) = 0.131\,m$$

Jednostruke uzengije URØ10/12.5 mogu prihvatiti napon:

$$\tau_{u,u}^{(1)} = \frac{2\times 0.785}{25\times 12.5}\times 40 = 0.201\,\frac{kN}{cm^2}$$

i dovoljne su na dužini:

$$\lambda_1 = \frac{\tau_{u,u}^{(1)}}{3\tau_r}(\lambda - x) = \frac{0.201}{0.33}\times(2.38 - 0.131) = 1.37\ m$$

dok je na preostalom delu dužine osiguranja 2.38 – 1.37 = 1.01 m potrebno postaviti dvostruke uzengije (ili, kao varijantno rešenje, vertikalne uzengije i koso povijene profile).

$\Delta A_a = 0$ *(»špic« momenta)*

Presek B^{desno}

$C_u = 1.6\times 18.0 + 1.8\times 39.7 = 100.3\ kN$

$$T_u^{B,d} = q_{u2}L_2 - C_u = 41.47\times 6.0 - 100.3 = 183.6\,kN$$

$$\tau_n^{B,d} = \frac{183.6}{25\times 0.9\times 53} = 0.154\,\frac{kN}{cm^2} \quad \begin{cases} > \tau_r = 1.1\,MPa \\ < 3\tau_r \end{cases}$$

$$L_{0,T} = 6.0 - 1.57 = 4.43\ m \Rightarrow \quad \lambda = 4.43\times\left(1 - \frac{0.11}{0.154}\right) = 1.27\ m$$

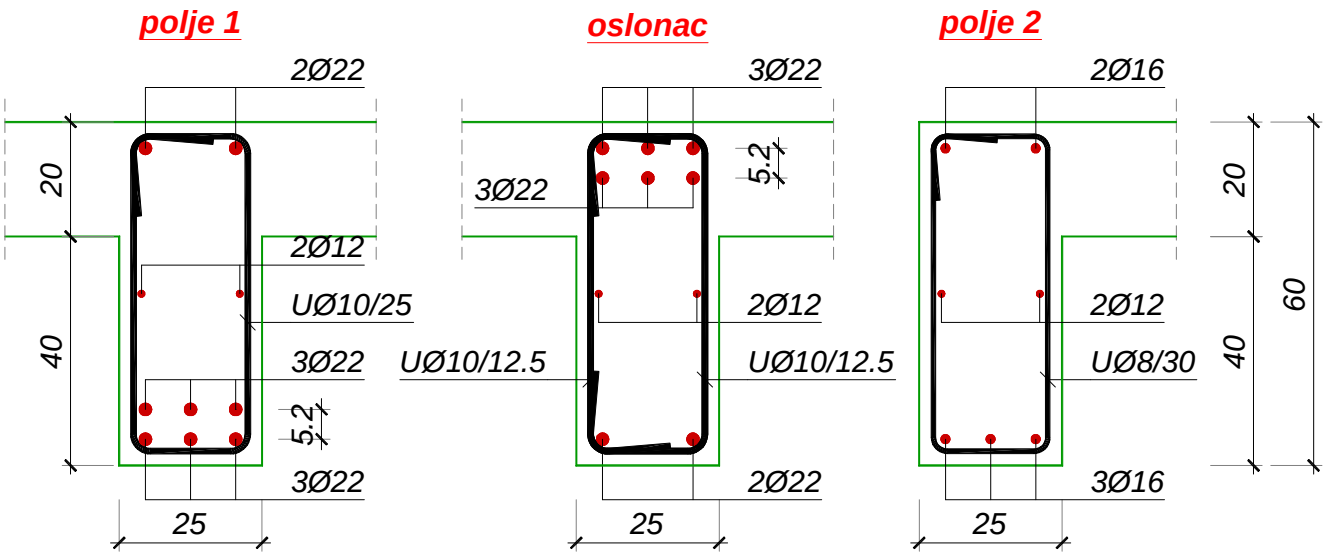
$$\tau_{Ru}^{B,d} = \frac{3}{2}\times(0.154 - 0.11) = 0.066\,\frac{kN}{cm^2}$$

$$e_u = \frac{2\times 0.503}{25\times 0.2\%} = 20.1\ cm \qquad \Rightarrow \quad \text{usvojeno } \textbf{URØ8/20}\ (m=2)$$

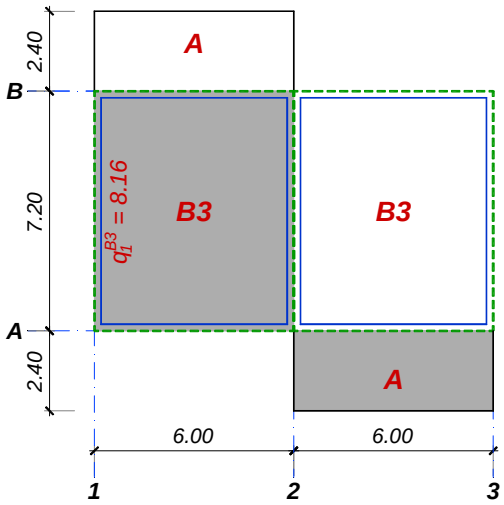
$$\tau_{u,u} = \frac{2\times 0.503}{25\times 20}\times 40 = 0.080\,\frac{kN}{cm^2} > \tau_{Ru,\max} = 0.066\,\frac{kN}{cm^2}$$

$\Delta A_a = 0$ *(»špic« momenta)*

Usvojeni poprečni preseci su prikazani na donjoj skici.



4. Proračun grede POS 3



$Q = 6.0 \times 7.2 \times 10.0/2 = 216\ kN$

$Q_1^{B3} = 0.272 \times 216 = 58.8\ kN$

$q_1^{B3} = \frac{58.8}{7.2} = 8.16\ \frac{kN}{m}$

$g = 3.75 + 6.78 = 10.53\ kN/m$

$R_g = 10.53 \times 7.2/2 = 37.9\ kN$

$p = 6.78 + 8.16 = 14.94\ kN/m$

$R_p = 14.94 \times 7.2/2 = 53.8\ kN$

$q_u = 1.6 \times 10.53 + 1.8 \times 14.94 = 43.74\ kNm/m$

$M_u = 43.74 \times 7.2^2/8 = 283.4\ kNm$

$$B = \min\begin{Bmatrix} 25 + \frac{720}{12} = 85 \\ 25 + 8 \times 20 = 185 \end{Bmatrix} = 85\ cm$$

$$k = \frac{53}{\sqrt{\frac{283.4 \times 10^2}{85 \times 2.05}}} = 4.156 \Rightarrow \begin{matrix} \varepsilon_b / \varepsilon_a = 1.326 / 10‰ \\ s = 0.117 \Rightarrow x = 0.117 \times 53 = 6.2\ cm < d_p = 20\ cm \\ \bar{\mu} = 6.043\% \end{matrix}$$

$$A_a = 6.043 \times \frac{85 \times 53}{100} \times \frac{2.05}{40} = 13.95\ cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{4RØ22}\ (15.21\ cm^2)$$

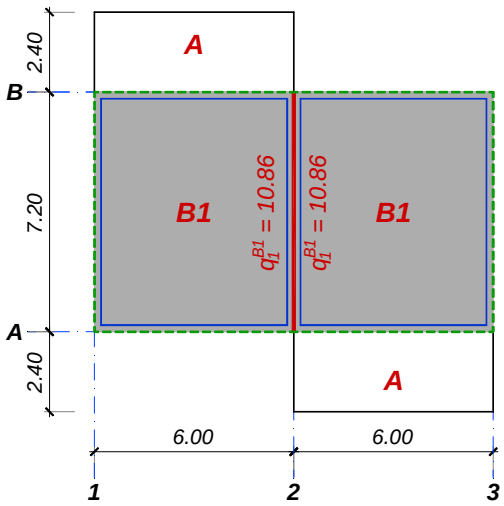
$$T_u = 1.6 \times 37.9 + 1.8 \times 53.8 = 157.5\ kN \quad \Rightarrow \quad \tau_n = \frac{157.5}{25 \times 0.9 \times 53} = 0.132\ \frac{kN}{cm^2}$$

$$\lambda = \frac{7.2}{2} \times \left(1 - \frac{0.11}{0.132}\right) = 0.60\ m \quad ; \quad \tau_{Ru} = \frac{3}{2} \times (0.132 - 0.11) = 0.033\ \frac{kN}{cm^2}$$

$$e_u = \frac{2 \times 0.503}{25 \times 0.2\%} = 20.1\ cm \quad \Rightarrow \quad \text{usvojeno } \mathbf{URØ8/20}\ (m=2)$$

$$\Delta A_a = \frac{157.5}{2 \times 40} \times (\cot 45° - \cot 90°) = 1.97\ cm^2 \Rightarrow \quad \text{usvojeno } \mathbf{2RØ22}\ (7.60\ cm^2)$$

5. Proračun grede POS 4



$Q = 6.0 \times 7.2 \times 10.0/2 = 216\ kN$

$Q_1^{B1} = 0.362 \times 216 = 78.2\ kN$

$q_1^{B1} = \frac{78.2}{7.2} = 10.86\ \frac{kN}{m}$

$g = 7.5 + 2 \times 9.93 = 27.36\ kN/m$

$R_g = 27.36 \times 7.2/2 = 98.5\ kN$

$p = 2 \times (9.93 + 10.86) = 41.58\ kN/m$

$R_p = 41.58 \times 7.2/2 = 149.7\ kN$

$q_u = 1.6 \times 27.36 + 1.8 \times 41.58 = 118.62\ kNm/m$

$M_u = 118.62\times 7.2^2/8 = 768.7\ kNm$

$$B = \min\left\{\begin{array}{l} 50+\dfrac{720}{4}=230 \\ 50+20\times 20 = 450 \end{array}\right\} = 230\,cm$$

$$k = \frac{53}{\sqrt{\dfrac{768.7\times 10^2}{230\times 2.05}}} = 4.151 \Rightarrow \begin{array}{l} \varepsilon_b/\varepsilon_a = 1.327/10‰ \\ s = 0.117 \Rightarrow x = 0.117\times 53 = 6.2\,cm < d_p = 20\,cm \\ \bar{\mu} = 6.057\% \end{array}$$

$$A_a = 6.057\times\frac{230\times 53}{100}\times\frac{2.05}{40} = 37.84\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{10RØ22}\ (38.01\ cm^2)$$

$T_u = 1.6\times 98.5 + 1.8\times 149.7 = 427.0\ kN$

$$\tau_n = \frac{427.0}{50\times 0.9\times 53} = 0.179\,\frac{kN}{cm^2} \quad \begin{cases} > \tau_r = 1.1\,MPa \\ < 3\tau_r \end{cases}$$

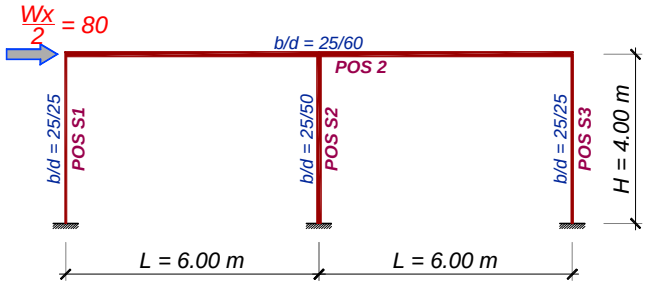
$$\lambda = \frac{7.2}{2}\times\left(1-\frac{0.11}{0.179}\right) = 1.39\,m \quad ; \quad \tau_{Ru} = \frac{3}{2}\times(0.179-0.11) = 0.104\,\frac{kN}{cm^2}$$

$$e_u = \frac{2\times 0.785}{50\times 0.104}\times 40 = 12.1\ cm \quad \Rightarrow \quad \text{usvojeno } \mathbf{URØ10/10}\ (m=2)$$

$$\Delta A_a = \frac{427.0}{2\times 40}\times(\cot 45° - \cot 90°) = 5.34\,cm^2 \quad \Rightarrow \quad \text{usvojeno } \mathbf{4RØ22}\ (15.21\ cm^2)$$

6. Raspodela uticaja od vetra na stubove

Vetar W_x prihvataju dva rama jednake krutosti (ose A i B), pa svaki prihvata polovinu ukupne sile. Unutar ovih ramova, stubovi S1 i S3 su dimenzija 25/25 cm, a središnji stubovi S2 dimenzija 25/50 cm, odnosno $(50/25)^3 = 8$ puta veće krutosti od ivičnih. Stoga ivični stubovi prihvataju 8 puta manju silu, odnosno:



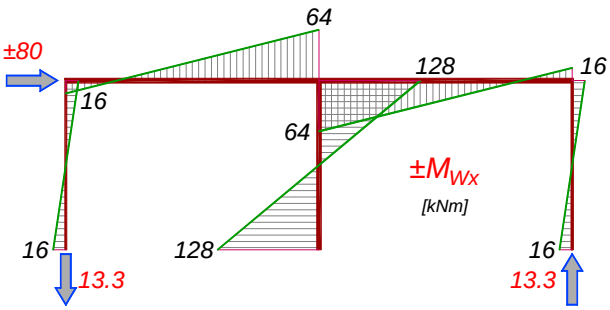
$$W_{x1} + 8W_{x1} + W_{x1} = 10W_{x1} = \frac{W_x}{2} = 80\,kN$$

$$W_{x1} = W_{x3} = 8\,kN \ ; \ W_{x2} = 64\,kN$$

$$M_{Wx,1} \approx \frac{W_{x1}H}{2} = \frac{8.0\times 4.0}{2} = 16\,kNm = M_{Wx,3}$$

$$M_{Wx,2} \approx \frac{W_{x2}H}{2} = \frac{64.0\times 4.0}{2} = 128\,kNm$$

$$A_W = -C_W = \frac{16+64}{6} = 13.3\,kN$$



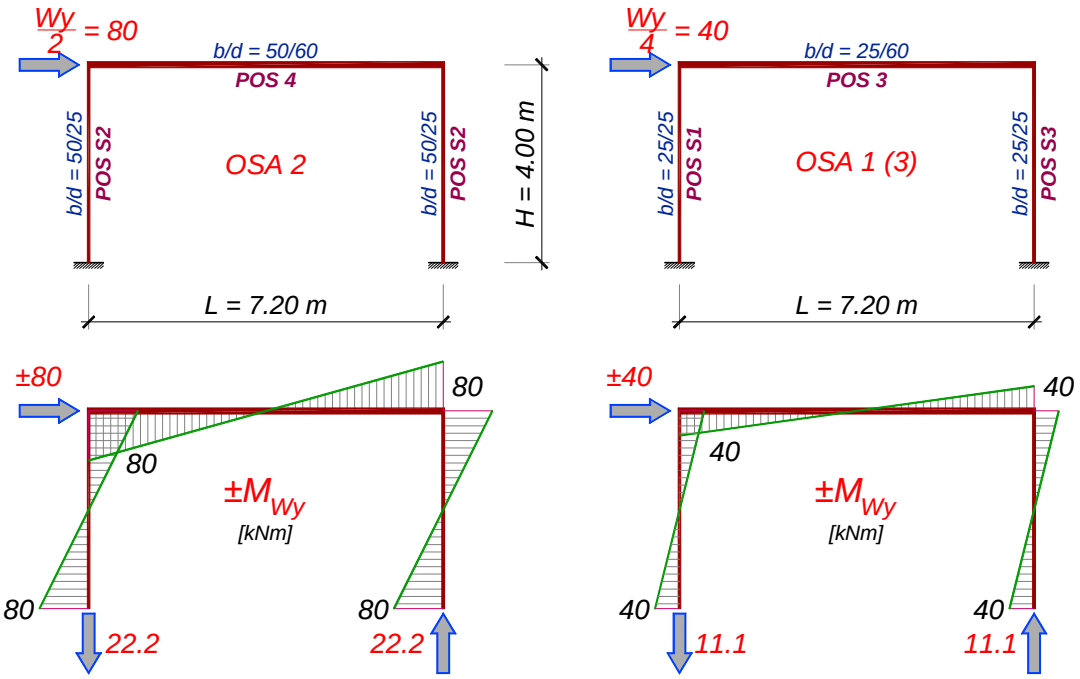
Vetar W_y prihvataju tri rama, od kojih su ivični ramovi (u osama 1 i 3) širine 25 cm, a srednji ram (osa 2) širine 50 cm, dakle dvaput veće krutosti. Stoga srednji ram prihvata polovinu, a ivični četvrtinu ukupne sile:

$$W_y^1 + W_y^2 + W_y^3 = W_y^1 + 2W_y^1 + W_y^1 = 4W_y^1 = W_y = 160\,kN \ \Rightarrow \ W_y^1 = 40\,kN \ ; \ W_y^2 = 80\,kN$$

Svaki ram formiraju dva stuba istog poprečnog preseka, visine i konturnih uslova, pa svaki od njih prihvata polovinu odgovarajuće sile od vetra:

$$M_{Wy,2} \approx \frac{80}{2} \times \frac{4.0}{2} = 80\,kNm \quad ; \quad A_w = -B_w = \frac{80+80}{7.2} = 22.2\,kN \quad (POS\ S2)$$

$$M_{Wy,1} \approx \frac{40}{2} \times \frac{4.0}{2} = 40\,kNm = M_{Wy,3} \; ; \quad A_w = -B_w = \frac{40+40}{7.2} = 11.1\,kN \quad (POS\ S1,\ S3)$$



7. Dimenzionisanje stubova POS S1, S3

Stubovi su opterećeni alternativnim momentima savijanja i biće armirani simetrično u oba pravca. Kako su oba stuba napregnuta istim momentima savijanja, potrebno je odrediti maksimalnu, odnosno minimalnu silu i sa njima izvršiti dimenzionisanje.

Kako je već naglašeno kod dimenzionisanja POS 2 (presek u prvom polju), maksimalna sila usled povremenog opterećenja u stubu S1 se javlja pri položaju povremenog opterećenja prikazanom na skici desno. Za isti položaj opterećenja se javlja i minimalna sila u stubu S3. Vrednosti reakcija POS 2 su već sračunate, pa je potrebno sračunati sile od povremenog opterećenja koje deluje na POS 3:

$$q_1^{B2} = \frac{Q_1^{B2}}{L_y} = \frac{0.244 \times 216}{7.2} = 7.32\,\frac{kN}{m}$$

$$p_{max}^{POS3} = 6.78 + 7.32 = 14.1\,kN/m$$

$$R_{p,max}^{POS3} = 14.1 \times 7.2/2 = 50.8\,kN$$

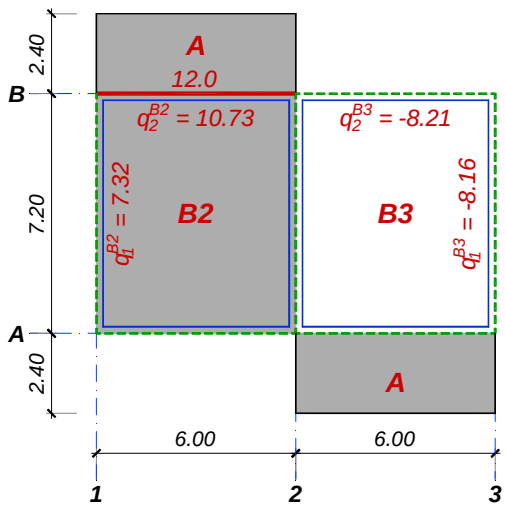
$$P_{max} = A_{p,max}^{POS2} + R_{p,max}^{POS3} = 116 + 50.8 = 166.8\,kN$$

$$q_1^{B3} = \frac{Q_1^{B3}}{L_y} = \frac{-0.272 \times 216}{7.2} = -8.16\,\frac{kN}{m}$$

$$p_{min}^{POS3} = 6.78 - 8.16 = -1.38\,kN/m$$

$$R_{p,min}^{POS3} = -1.38 \times 7.2/2 = -5.0\,kN$$

$$P_{min} = C_{p,min}^{POS2} + R_{p,min}^{POS3} = -20.5 - 5.0 = -25.5\,kN$$



Ukupna sila u stubovima S1 i S3 se dobija superponiranjem reakcija greda POS 2 i POS 3:

stub POS S1:

$G = A_{g2} + R_{g3} = 61.7 + 37.9 = 99.6$ kN

$P_{max} = 166.8$ kN

stub POS S3:

$G = C_{g2} + R_{g3} = 18.0 + 37.9 = 55.9$ kN

$P_{min} = -25.5$ kN

Podužni pravac (vetar W_x) – b/d = 25/25 cm

$\pm M_u = 1.8\times16 = 28.8$ kNm $\Rightarrow$ $m_u = \dfrac{28.8\times10^2}{25\times25^2\times2.05} = 0.090$

$N_{u,min} = 1.0\times G + 1.8\times(P_{min} + Z_w) = 1.0\times55.9 + 1.8\times(-25.5 - 13.3) = -13.8$ kN

$n_u = \dfrac{-13.8}{25\times25\times2.05} = -0.011 \Rightarrow \bar{\mu}_1 = 0.124$; $\varepsilon_{a1} = 10‰$

$N_{u,max} = 1.6\times G + 1.8\times(P_{max} + N_w) = 1.6\times99.6 + 1.8\times(166.8 + 13.3) = 483.6$ kN

$n_u = \dfrac{483.6}{25\times25\times2.05} = 0.377 \Rightarrow \bar{\mu}_1 = 0$; $\varepsilon_{a1} = 2.66‰$; $\gamma_{ug} = 1.634, \gamma_{up} = 1.834$

Nakon korekcije koeficijenata sigurnosti sledi:

$\pm M_u = 1.852\times20 = 29.6$ kNm $\Rightarrow$ $m_u = \dfrac{29.6\times10^2}{25\times25^2\times2.05} = 0.093$

$N_{u,max} = 1.652\times99.6 + 1.852\times(166.8 + 13.3) = 498.2$ kN

$n_u = \dfrac{498.2}{25\times25\times2.05} = 0.389 \Rightarrow \bar{\mu}_1 = 0$; $\varepsilon_{a1} = 2.48‰$; $\gamma_{ug} = 1.652, \gamma_{up} = 1.852$

Merodavna je kombinacija sa minimalnom normalnom silom ($\bar{\mu}_1 = 0.124 > 0$) pa sledi:

$A_{a1} = A_{a2} = 0.124\times25\times25\times\dfrac{2.05}{40} = 3.96\,cm^2$

Poprečni pravac (vetar W_y) – b/d = 25/25 cm

$\pm M_u = 1.8\times40 = 72$ kNm $\Rightarrow$ $m_u = \dfrac{72\times10^2}{25\times25^2\times2.05} = 0.225$

$N_{u,min} = 1.0\times G + 1.8\times(P_{min} + Z_w) = 1.0\times55.9 + 1.8\times(-25.5 - 11.1) = -9.8$ kN

$n_u = \dfrac{-9.8}{25\times25\times2.05} = -0.008 \Rightarrow \bar{\mu}_1 = 0.331$; $\varepsilon_{a1} = 8.89‰$

$N_{u,max} = 1.6\times G + 1.8\times(P_{max} + N_w) = 1.6\times99.6 + 1.8\times(166.8 + 11.1) = 479.6$ kN

$n_u = \dfrac{479.6}{25\times25\times2.05} = 0.374 \Rightarrow \bar{\mu}_1 = 0.171$; $\varepsilon_{a1} = 2.71‰$; $\gamma_{ug} = 1.629, \gamma_{up} = 1.829$

Nakon korekcije koeficijenata sigurnosti sledi:

$\pm M_u = 1.845\times50 = 73.8$ kNm $\Rightarrow$ $m_u = \dfrac{73.8\times10^2}{25\times25^2\times2.05} = 0.230$

$N_{u,max} = 1.645\times99.6 + 1.845\times(166.8 + 11.1) = 492.1$ kN

$$n_u = \frac{492.1}{25\times25\times2.05} = 0.384 \;\Rightarrow\; \bar{\mu}_1 = 0.178 \;;\; \varepsilon_{a1} = 2.55‰ \;;\; \gamma_{ug} = 1.645, \gamma_{up} = 1.845$$

Merodavna je kombinacija sa minimalnom normalnom silom ($\bar{\mu}_1 = 0.331 > 0.178$) pa sledi:

$$A_{a1} = A_{a2} = 0.331\times25\times25\times\frac{2.05}{40} = 10.59\,cm^2$$

8. Dimenzionisanje stuba POS S2

I ovi stubovi će biti armirani simetrično u oba pravca i dimenzionisani pomoću dijagrama interakcije za pravougaoni presek. Kao i u slučaju stubova S1 i S3, ponovo je potrebno odrediti maksimalnu, odnosno minimalnu silu i sa njima izvršiti dimenzionisanje.

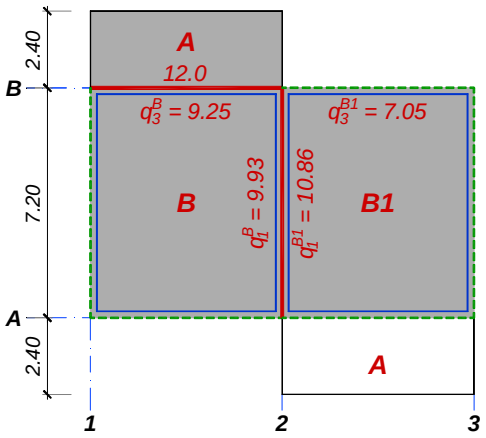
Maksimalna sila usled povremenog opterećenja u stubu S2 se javlja pri položaju opterećenja prikazanom na skici desno gore. Vrednost srednje reakcije grede POS 2 je već sračunata, pa je potrebno sračunati silu od povremenog opterećenja koje deluje na POS 4:

$$q_1^{B1} = \frac{Q_1^{B1}}{L_y} = \frac{0.362\times216}{7.2} = 10.86\,\frac{kN}{m}$$

$$p_{max}^{POS4} = 2\times9.93 + 9.93 + 10.86 = 40.65\,kN/m$$

$$R_{p,max}^{POS4} = 40.65\times7.2/2 = 146.3\,kN$$

$$P_{max} = B_{p,max}^{POS2} + R_{p,max}^{POS4} = 211 + 146.3 = 357.3\,kN$$



Minimalna sila usled povremenog opterećenja se javlja pri položaju opterećenja prikazanom na skici desno dole. Kako su konturni uslovi isti kao za maksimalnu silu, razlikuju se samo znaci antimetričnog dela opterećenja:

$$p_{min}^{POS4} = 2\times9.93 - 9.93 - 10.86 = -0.93\,kN/m$$

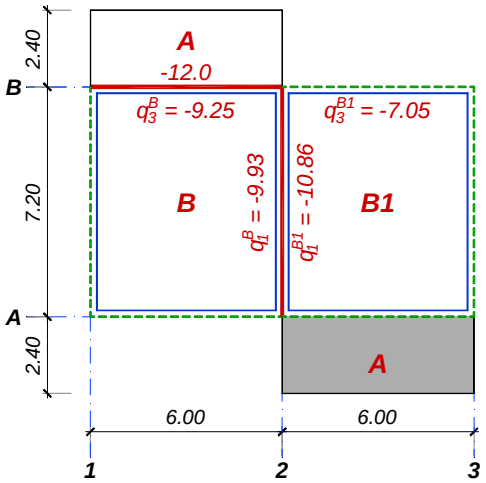
$$R_{p,min}^{POS4} = -0.93\times7.2/2 = -3.3\,kN$$

$$p_{1,min}^{POS2} = 12 + 9.25 - 12 - 9.25 = 0$$

$$p_{2,min}^{POS2} = 6.70 - 7.05 = -0.35\,kN/m$$

$$B_{p,min} = \frac{5\times(0-0.35)}{8}\times6.0 = -1.4\,kN$$

$$P_{min} = B_{p,min}^{POS2} + R_{p,min}^{POS4} = -1.4 - 3.3 = -4.7\,kN$$



Konačno, sila u stubu S2 usled stalnog opterećenja je:

$$G = B_{g2} + R_{g4} = 132.9 + 98.5 = 231.4\,kN$$

Podužni pravac (vetar W_x) – b/d = 25/50 cm

$$\pm M_u = 1.8\times128 = 230.4\,kNm \quad\Rightarrow\quad m_u = \frac{230.4\times10^2}{25\times50^2\times2.05} = 0.18$$

$$N_{u,min} = 1.0\times G + 1.8\times P_{min} = 1.0\times231.4 + 1.8\times(-4.7) = 223.0\,kN$$

$$n_u = \frac{223.0}{25\times50\times2.05} = 0.087 \;\Rightarrow\; \bar{\mu}_1 = 0.173 \;;\; \varepsilon_{a1} = 10‰$$

$N_{u,\max} = 1.6\times G + 1.8\times P_{\max} = 1.6\times 231.4 + 1.8\times 357.3 = 1013.4\ kN$

$$n_u = \frac{1013.4}{25\times 50\times 2.05} = 0.395 \Rightarrow \bar{\mu}_1 = 0.076\ ;\ \varepsilon_{a1} = 3.02‰$$

Merodavna je kombinacija sa minimalnom normalnom silom ($\bar{\mu}_1 = 0.173 > 0.076$) *pa sledi:*

$$A_{a1} = A_{a2} = 0.173\times 25\times 50\times \frac{2.05}{40} = 11.08\,cm^2$$

Poprečni pravac (vetar W_y) – b/d = 50/25 cm

$$\pm M_u = 1.8\times 80 = 144\ kNm \quad \Rightarrow \quad m_u = \frac{144\times 10^2}{50\times 25^2\times 2.05} = 0.225$$

$N_{u,\min} = 1.0\times G + 1.8\times(P_{\min} + Z_w) = 1.0\times 231.4 + 1.8\times(-4.7 - 22.2) = 183.0\ kN$

$$n_u = \frac{183.0}{50\times 25\times 2.05} = 0.071 \Rightarrow \bar{\mu}_1 = 0.292\ ;\ \varepsilon_{a1} = 7.78‰$$

$N_{u,\max} = 1.6\times G + 1.8\times(P_{\max} + N_w) = 1.6\times 231.4 + 1.8\times(357.3 + 22.2) = 1053.4\ kN$

$$n_u = \frac{1053.4}{50\times 25\times 2.05} = 0.411 \Rightarrow \bar{\mu}_1 = 0.166\ ;\ \varepsilon_{a1} = 2.15‰\ ;\ \gamma_{ug} = 1.685, \gamma_{up} = 1.885$$

Nakon korekcije koeficijenata sigurnosti sledi:

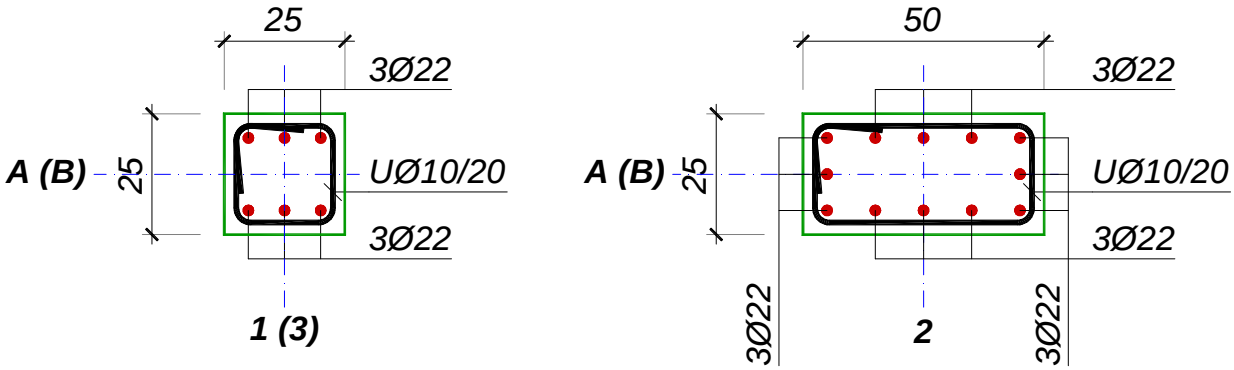
$$\pm M_u = 1.914\times 80 = 153.1\ kNm \quad \Rightarrow \quad m_u = \frac{153.1\times 10^2}{50\times 25^2\times 2.05} = 0.239$$

$N_{u,\max} = 1.714\times 231.4 + 1.914\times(357.3 + 22.2) = 1123.2\ kN$

$$n_u = \frac{1123.2}{50\times 25\times 2.05} = 0.438 \Rightarrow \bar{\mu}_1 = 0.188\ ;\ \varepsilon_{a1} = 1.86‰\ ;\ \gamma_{ug} = 1.714, \gamma_{up} = 1.914$$

Merodavna je kombinacija sa minimalnom normalnom silom ($\bar{\mu}_1 = 0.292 > 0.188$) *pa sledi:*

$$A_{a1} = A_{a2} = 0.292\times 50\times 25\times \frac{2.05}{40} = 18.68\,cm^2$$



Ugaoni stubovi (POS S1, POS S3):

$A_{a1,x} = 2RØ22 = 7.60\ cm^2 > A_{a,potr.} = 3.96\ cm^2$

$A_{a1,y} = 3RØ22 = 11.40\ cm^2 > A_{a,potr.} = 10.59\ cm^2$

Srednji stubovi (POS S2):

$A_{a1,x} = 3RØ22 = 11.40\ cm^2 > A_{a,potr.} = 11.08\ cm^2$

$A_{a1,y} = 5RØ22 = 19.01\ cm^2 > A_{a,potr.} = 18.68\ cm^2$