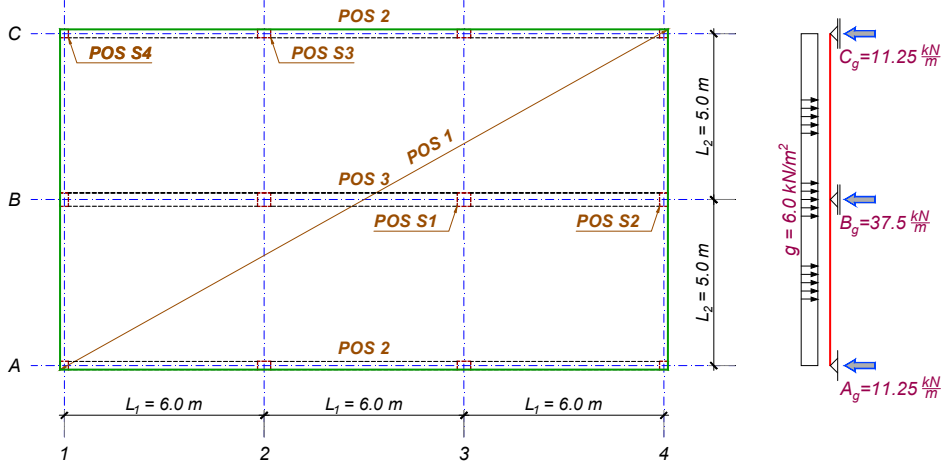


Ploča POS 1 – stalno opterećenje

1

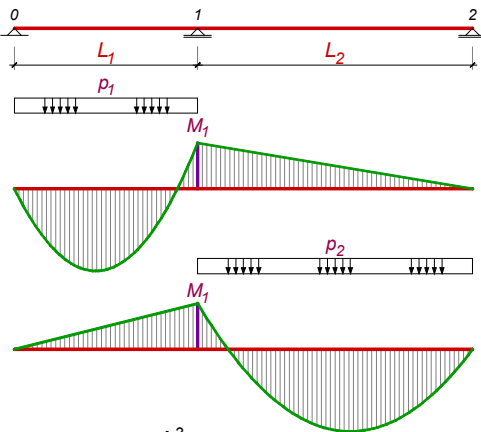
1.2 ANALIZA OPTEREĆENJA ZA POS 1

- sopstvena težina ploče $0.14 \times 25 = 3.5 \text{ kN/m}^2$
- dodatno stalno opterećenje $A_g = 2.5 \text{ kN/m}^2$
- ukupno, stalno opterećenje $g = 6.0 \text{ kN/m}^2$
- povremeno opterećenje: $p = 4.0 \text{ kN/m}^2$



Kontinualni nosač preko dva polja

2



$$M_1 = -\frac{p_1 \times L_1^3}{8 \times (L_1 + L_2)}$$

$$M_1 = -\frac{p_2 \times L_2^3}{8 \times (L_1 + L_2)}$$

opterećeno polje			
L_2/L_1	p_1	p_2	p_1+p_2
0.5	-0.0833	-0.0104	-0.0938
0.6	-0.0781	-0.0169	-0.0950
0.7	-0.0735	-0.0252	-0.0988
0.8	-0.0694	-0.0356	-0.1050
0.9	-0.0658	-0.0480	-0.1138
1	-0.0625	-0.0625	-0.1250
1.1	-0.0595	-0.0792	-0.1388
1.2	-0.0568	-0.0982	-0.1550
	$\times pL_1^2$	$\times pL_1^2$	$\times pL_1^2$

Ploča POS 1 – položaji povremenog opterećenja

3

1.3.2 Maksimalni moment u polju

Maksimalni moment u polju se javlja kada se povremeno opterećenje nalazi samo u tom polju. Istovremeno se javlja maksimalna reakcija A_{p1} i minimalna reakcija C_{p1} . Nepoznata vrednost oslonačkog momenta savijanja je:

$$M_{p1} = -\frac{p_1 L_1^3}{8(L_1 + L_2)} = -\frac{p_1 L^2}{16} = -\frac{4.0 \times 5.0^2}{16} = -6.25 \frac{\text{kNm}}{\text{m}}$$

dok su odgovarajuće reakcije krajnjih oslonaca:

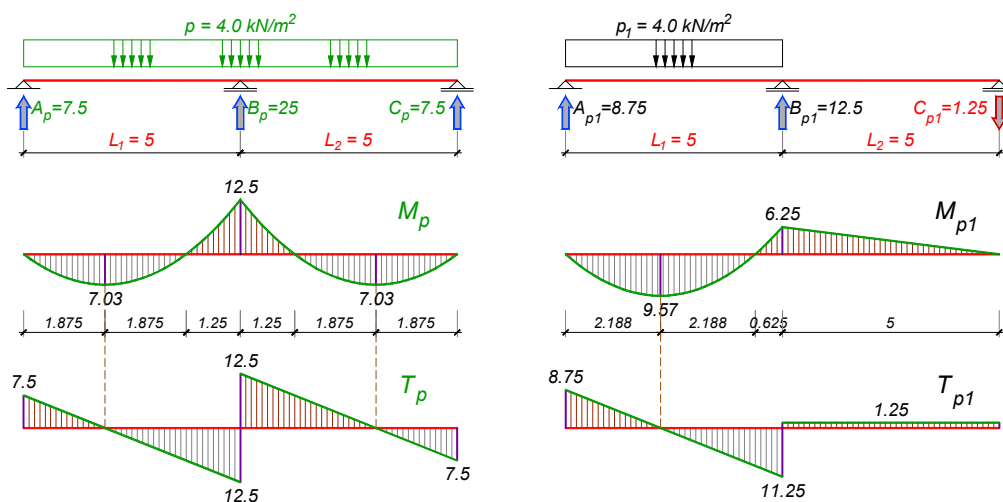
$$A_{p1} = \frac{p_1 L_1}{2} + \frac{M_{p1}}{L_1} = \frac{p_1 L}{2} - \frac{p_1 L^2}{16 L_1} = \frac{7}{16} p_1 L = \frac{7}{16} \times 4.0 \times 5.0 = 8.75 \frac{\text{kN}}{\text{m}} = A_{p,\max}$$

$$C_{p1} = \frac{M_1}{L_2} = \frac{p_1 L^2}{16 L_2} = \frac{p_1 L}{16} = \frac{4.0 \times 5.0}{16} = -1.25 \frac{\text{kN}}{\text{m}} = C_{p,\min}$$

Na narednoj skici su prikazani dijagrami presečnih sila i reakcije oslonaca usled povremenog opterećenja koje deluje po čitavoj ploči, odnosno samo u prvom polju.

Ploča POS 1 – položaji povremenog opterećenja

4



Ploča POS 1 – maksimalni moment u polju

5

$$A_{u,\max} = 1.6 \times A_g + 1.8 \times A_{p1} = 1.6 \times 11.25 + 1.8 \times 8.75 = 33.8 \frac{\text{kN}}{\text{m}}$$

$$q_u = 1.6 \times 6.0 + 1.8 \times 4.0 = 16.8 \frac{\text{kN}}{\text{m}^2} \Rightarrow x_{\max} = \frac{33.8}{16.8} = 2.01 \text{ m}$$

$$M_{u,\max} = 33.8 \times 2.01 - \frac{16.8 \times 2.01^2}{2} = 33.9 \frac{\text{kNm}}{\text{m}}$$

$$\text{pretp. } \emptyset 12 \Rightarrow h = d - \left(a_0 + \frac{\emptyset}{2}\right) = 14 - \left(2 + \frac{1.2}{2}\right) = 11.4 \text{ cm}$$

$$k = \frac{11.4}{\sqrt{\frac{33.9}{2.05}}} = 2.803 \Rightarrow \varepsilon_b/\varepsilon_a = 2.366/10\% ; \bar{\mu} = 13.741\%$$

$$A_a = 13.741 \times 11.4 \times \frac{2.05}{40} = 8.03 \frac{\text{cm}^2}{\text{m}} \Rightarrow e_a \leq \frac{100 \times 1.13}{8.03} = 14.1 \text{ cm}$$

usvojeno: **RØ12/12.5** (9.08 cm²/m)

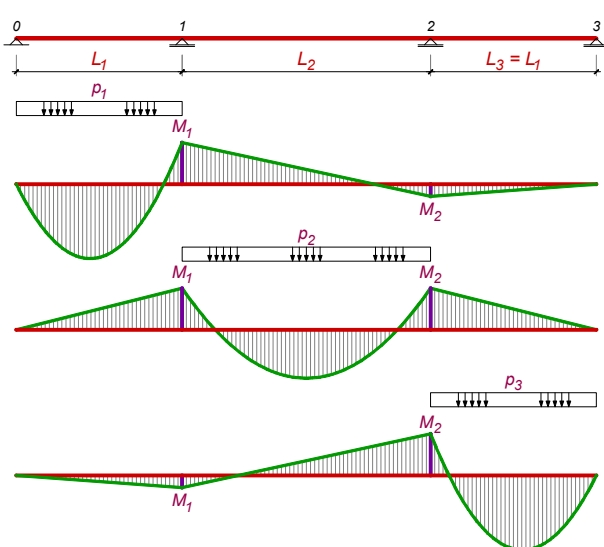
$$A_{ap} = 0.2 \times 8.03 = 1.61 \text{ cm}^2/\text{m} > A_{ap,\min} = 0.085 \times 14 = 1.19 \text{ cm}^2/\text{m}$$

$$\text{usv. } \emptyset 8 \text{ (} a_a^{(1)} = 0.503 \text{ cm}^2\text{): } e_{ap} \leq \frac{100 \times 0.503}{1.61} = 31.3 \text{ cm}$$

usvojeno: **RØ8/30** (1.68 cm²/m)

Kontinualni nosač preko tri polja

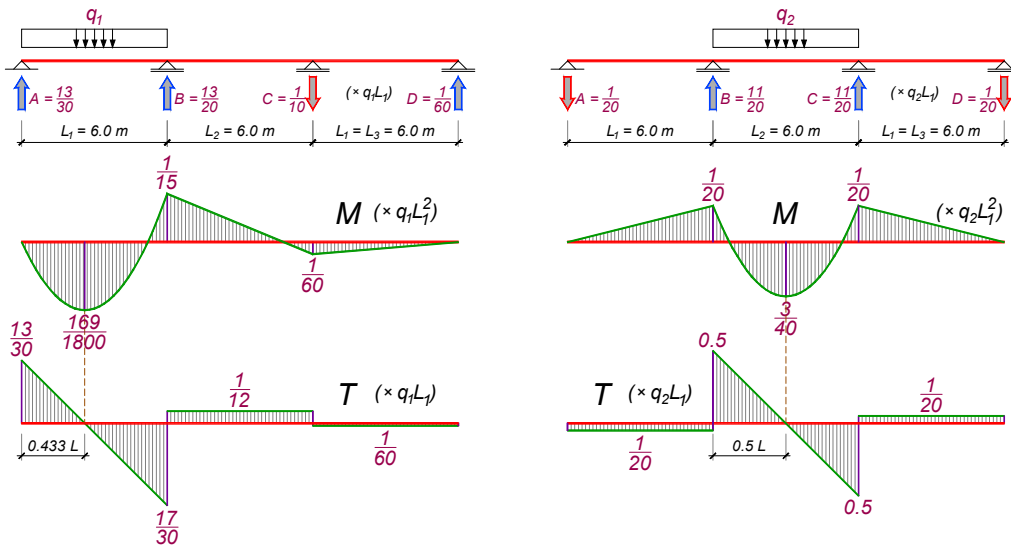
6



L_2/L_1	opterećeno polje		
	p_1	p_2	p_3
0.5	-0.0857	-0.0089	0.0143
0.6	-0.0810	-0.0142	0.0152
0.7	-0.0768	-0.0209	0.0158
0.8	-0.0731	-0.0291	0.0162
0.9	-0.0697	-0.0388	0.0165
1	-0.0667	-0.0500	0.0167
1.1	-0.0639	-0.0628	0.0167
1.2	-0.0614	-0.0771	0.0167
	$\times pL_1^2$	$\times pL_1^2$	$\times pL_1^2$

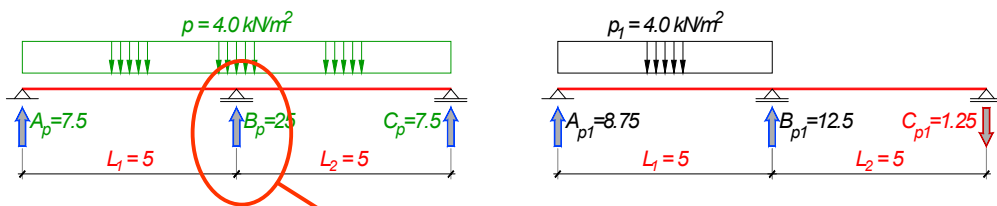
Kontinualni nosač preko tri polja

7



Srednja greda – POS 3

8



2.2 ANALIZA OPTEREĆENJA ZA POS 3

Stalno opterećenje je sračunato u primeru P7:

ukupno, stalno opterećenje $g = 42.5\text{ kN/m}$

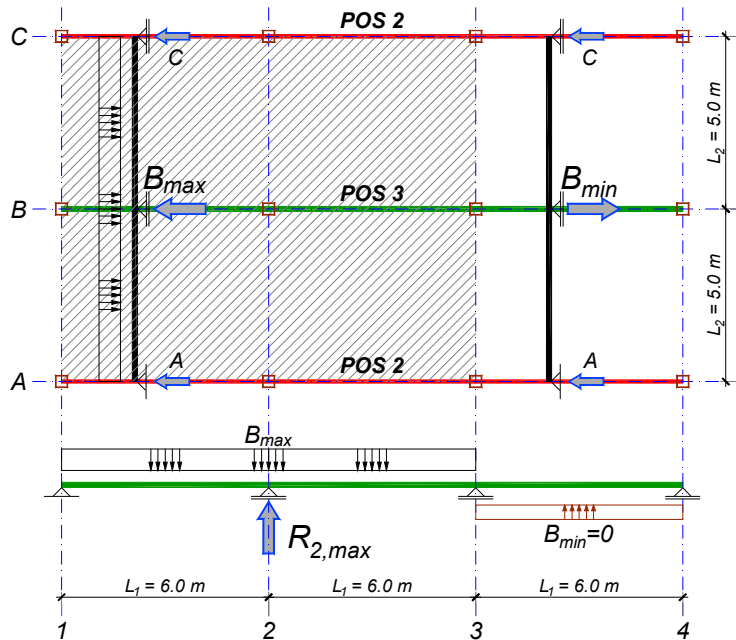
dok je maksimalna vrednost reakcije B_p usled povremenog opterećenja sračunata u 1.3.1. Kako se ni za jedan položaj povremenog opterećenja na ploči ne može dobiti negativna reakcija srednjeg oslonca, sledi:

povremeno opterećenje od POS 1: $B_{p,\max} = p_{\max} = 25.0\text{ kN/m}$

povremeno opterećenje od POS 1: $B_{p,\min} = p_{\min} = 0$

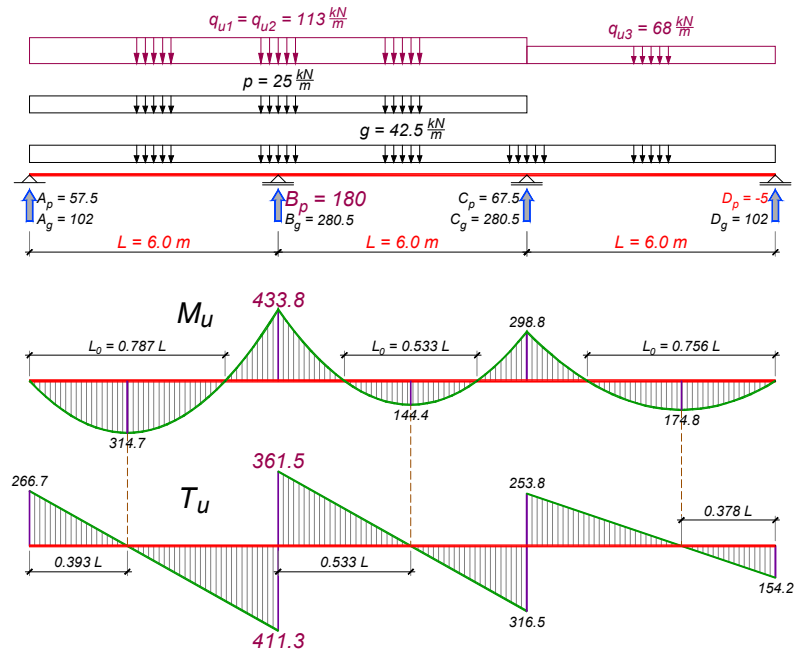
POS 3 - maksimalni moment nad osloncem

9



POS 3 - maksimalni moment nad osloncem

10



$$q_{u,\max} = 1.6 \times 42.5 + 1.8 \times 25.0 = 113 \text{ kN/m} = q_{u1} = q_{u2}$$

$$q_{u,\min} = 1.6 \times 42.5 = 68 \text{ kN/m} = q_{u3}$$

$$M_{1u} = -\left(\frac{q_{u1}}{15} + \frac{q_{u2}}{20} - \frac{q_{u3}}{60}\right) \times L_1^2 = -\left(\frac{113}{15} + \frac{113}{20} - \frac{68}{60}\right) \times 6.0^2 = -433.8 \text{ kNm}$$

$$M_{2u} = -\left(\frac{q_{u3}}{15} + \frac{q_{u2}}{20} - \frac{q_{u1}}{60}\right) \times L_1^2 = -\left(\frac{68}{15} + \frac{113}{20} - \frac{113}{60}\right) \times 6.0^2 = -298.8 \text{ kNm}$$

Maksimalna reakcija oslonca B usled povremenog opterećenja:

$$M_{1p} = -\left(\frac{25}{15} + \frac{25}{20}\right) \times 6.0^2 = -105 \text{ kNm} \Rightarrow A_p = \frac{25 \times 6.0}{2} - \frac{105}{6.0} = 57.5 \text{ kN}$$

$$M_{2p} = -\left(\frac{25}{20} - \frac{25}{60}\right) \times 6.0^2 = -30 \text{ kNm} \Rightarrow B_p = \frac{1}{6.0} \times \left(25 \times \frac{12.0^2}{2} - 30 - 57.5 \times 12.0\right) = 180 \text{ kN}$$

$$T_u^A = 1.6 \times 102 + 1.8 \times 57.5 = 266.7 \text{ kN} \Rightarrow T_u^{B,\text{levo}} = 266.7 - 113 \times 6.0 = -411.3 \text{ kN}$$

$$B_u = 1.6 \times 280.5 + 1.8 \times 180 = 772.8 \text{ kN} \Rightarrow T_u^{B,\text{desno}} = 772.8 - 411.3 = 361.5 \text{ kN}$$

2.3.1.1 Dimenzionisanje prema momentu savijanja

$$\text{pretp. } a_1 = 7 \text{ cm} \Rightarrow b/d/h = 40/50/43 \text{ cm}$$

$$k = \frac{43}{\sqrt{\frac{433.8 \times 10^2}{40 \times 2.05}}} = 1.870 \Rightarrow \begin{cases} \varepsilon_b / \varepsilon_a = 3.5 / 4.629\% \\ \mu = 34.853\% \end{cases}$$

$$A_a = 34.853 \times \frac{40 \times 43}{100} \times \frac{2.05}{40} = 30.72 \text{ cm}^2 \Rightarrow \text{usv.: } \mathbf{8R\check{O}22} \text{ (30.41 cm}^2\text{)}$$

Umesto korekcije statičke visine, ovde je sproveden dokaz nosivosti usvojenog preseka:

$$a_1 = \frac{5 \times 4.5 + 3 \times 10}{8} = 6.56 \text{ cm} \Rightarrow h = 50 - 6.56 = 43.44 \text{ cm}$$

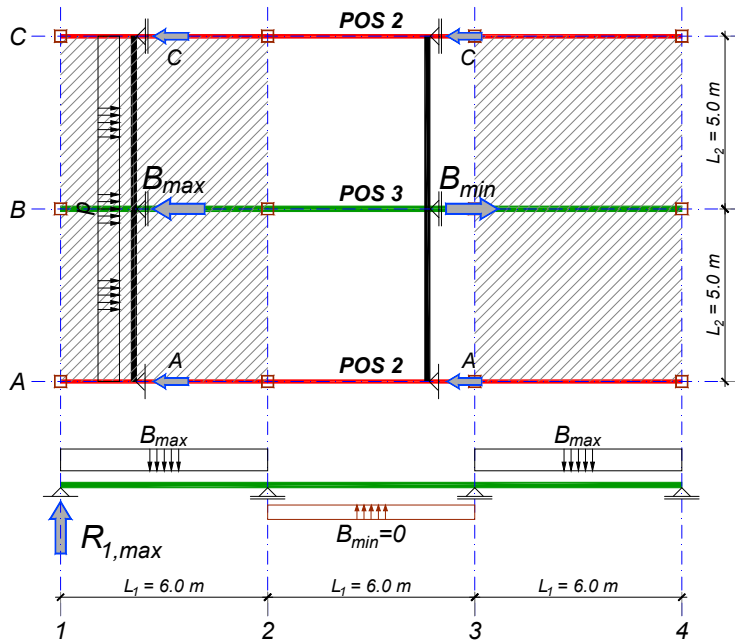
$$\bar{\mu} = \frac{30.41 \times 40}{40 \times 43.44 \times 2.05} = 0.34151 = 34.151\% \Rightarrow \begin{cases} \varepsilon_b / \varepsilon_a \approx 3.5 / 4.8\% \\ k = 1.885 \end{cases}$$

$$M_u = \left(\frac{43.44}{1.885}\right)^2 \times 40 \times 2.05 \times 10^{-2} = 435.4 \text{ kNm} > M_{u,\max} = 433.8 \text{ kNm}$$

Nosivost usvojenog preseka je dovoljna.

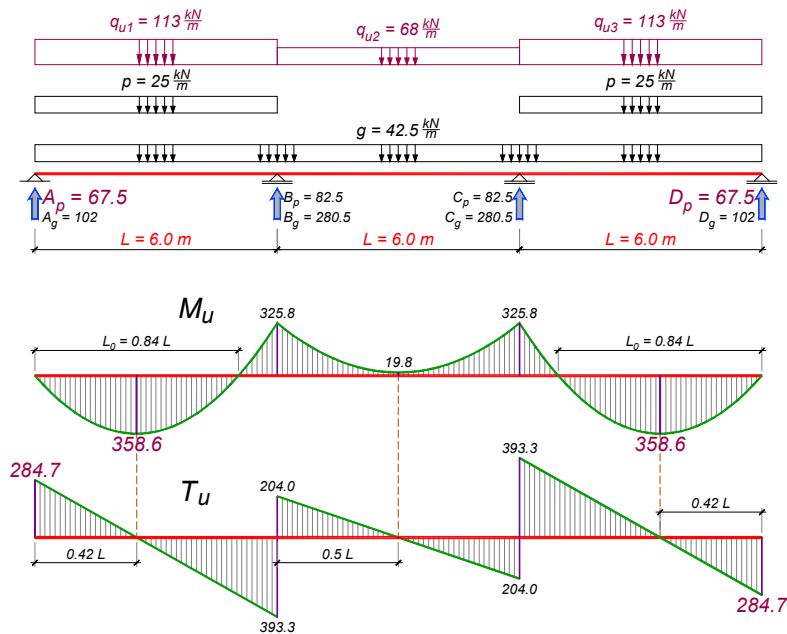
POS 3 - maksimalni moment u krajnjem polju

13



POS 3 - maksimalni moment u krajnjem polju

14



POS 3 - maksimalni moment u krajnjem polju

15

2.3.2.1 Dimenzionisanje prema momentu savijanja

$$M_{1u} = -\left(\frac{q_{u1}}{15} + \frac{q_{u2}}{20} - \frac{q_{u3}}{60}\right) \times L_1^2 = -\left(\frac{113}{15} + \frac{68}{20} - \frac{113}{60}\right) \times 6.0^2 = -325.8 \text{ kNm} = M_{2u}$$

Maksimalna reakcija oslonca A usled povremenog opterećenja:

$$M_{1p} = -\left(\frac{25}{15} - \frac{25}{60}\right) \times 6.0^2 = -45 \text{ kNm} \Rightarrow A_p = \frac{25 \times 6.0}{2} - \frac{45}{6.0} = 67.5 \text{ kN} = A_{p,\max}$$

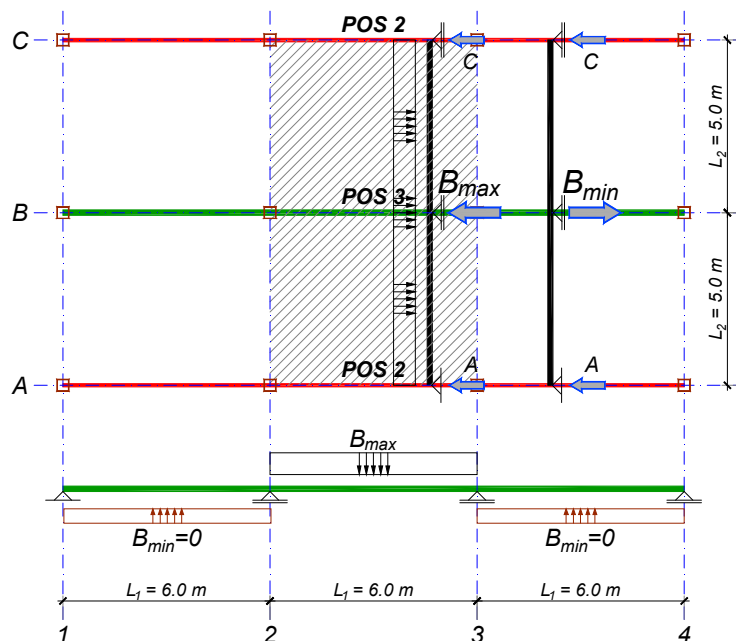
$$T_u^A = 1.6 \times 102 + 1.8 \times 67.5 = 284.7 \text{ kN} \Rightarrow x_{\max} = \frac{284.7}{113} = 2.52 \text{ m}$$

$$M_{u,\max}^{01} = 284.7 \times 2.52 - \frac{113 \times 2.52^2}{2} = 358.6 \text{ kNm}$$

$$L_o^{01} = 2x_{\max} = 2 \times 2.52 = 5.04 \text{ m} \Rightarrow B = \min \left\{ \begin{array}{l} 40 + 20 \times 14 = 320 \\ 40 + 0.25 \times 504 = 166 \end{array} \right\} = 166 \text{ cm}$$

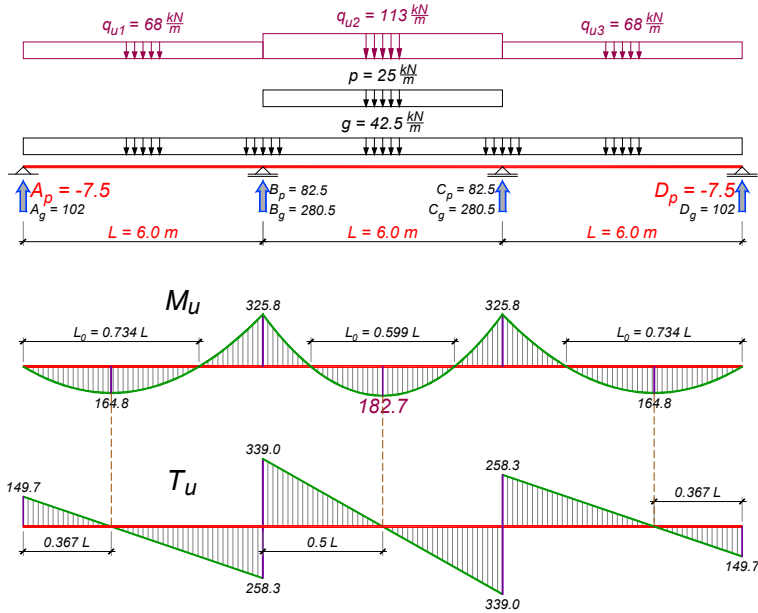
POS 3 - maksimalni moment u srednjem polju

16



POS 3 - maksimalni moment u srednjem polju

17



18

$$M_{1u} = -\left(\frac{q_{u1}}{15} + \frac{q_{u2}}{20} - \frac{q_{u3}}{60}\right) \times L_1^2 = -\left(\frac{113}{15} + \frac{68}{20} - \frac{113}{60}\right) \times 6.0^2 = -325.8 \text{ kNm} = M_{2u}$$

$$M_{1p} = -\left(\frac{25}{15} - \frac{25}{60}\right) \times 6.0^2 = -45 \text{ kNm} \Rightarrow A_p = -\frac{45}{6.0} = -7.5 \text{ kN} = A_{p,\min}$$

$$M_{u,\max}^{12} = \frac{113 \times 6.0^2}{8} + M_{1u} = 508.5 - 325.8 = 182.7 \text{ kNm}$$

$$L_0^2 = L \sqrt{\frac{M_{u,\max}^{12}}{f}} = 6.0 \times \sqrt{\frac{182.7}{508.5}} = 3.60 \text{ m} = \sqrt{\frac{8 \times M_{u,\max}^{12}}{q_u}}$$

$$B = \min \left\{ \begin{array}{l} 40 + 20 \times 14 = 320 \\ 40 + 0.25 \times 360 = 130 \end{array} \right\} = 130 \text{ cm}$$

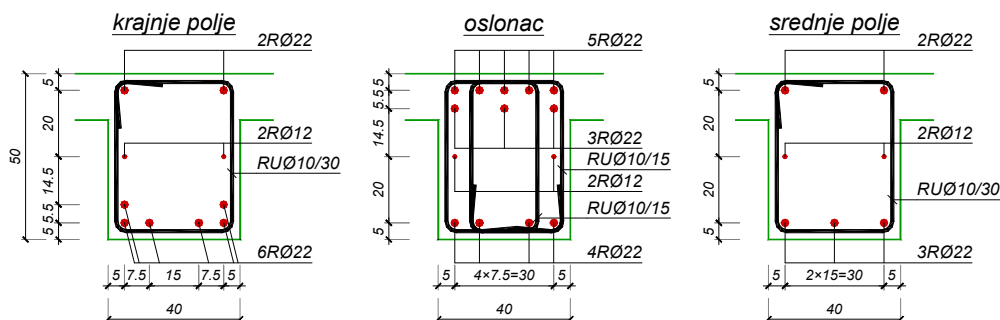
$$\text{pretp. } a_1 = 5 \text{ cm} \quad \Rightarrow \quad B/b/d/h/d_p = 130/40/50/45/14 \text{ cm}$$

$$k = \frac{45}{\sqrt{\frac{182.7 \times 10^2}{130 \times 2.05}}} = 5.433 \Rightarrow \begin{cases} \varepsilon_b / \varepsilon_a = 0.954 / 10\% \\ s = 0.087 \Rightarrow x = 0.087 \times 45 = 3.9 \text{ cm} < d_p = 14 \text{ cm} \\ \bar{\mu} = 3.494\% \end{cases}$$

$$A_a = 3.494 \times \frac{130 \times 45}{100} \times \frac{2.05}{40} = 10.47 \text{ cm}^2 \Rightarrow \text{usv.: } \mathbf{3R\text{\O}22} \text{ (11.40 cm}^2\text{)}$$

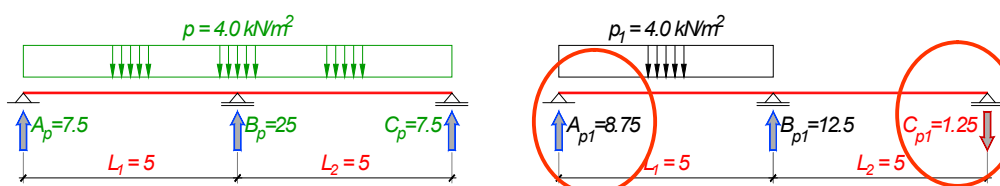
POS 3 – karakteristični preseki

19



Ivična greda – POS 2

20



3.2 ANALIZA OPTEREĆENJA ZA POS 2

Stalno opterećenje je sračunato u primeru P7:

ukupno, stalno opterećenje

$$g = 31.325 \text{ kN/m}$$

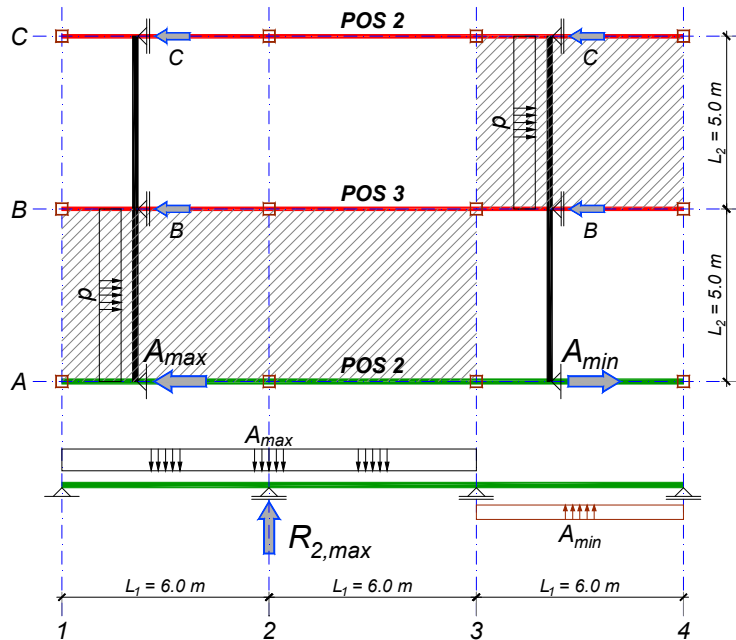
dok su maksimalna, odnosno minimalna vrednost reakcije A_p (C_p) usled povremenog opterećenja sračunate u tački 1.3.2:

povremeno opterećenje od POS 1: $A_{p,\max} = p_{\max} = 8.75 \text{ kN/m}$

povremeno opterećenje od POS 1: $C_{p,\min} = p_{\min} = -1.25 \text{ kN/m}$

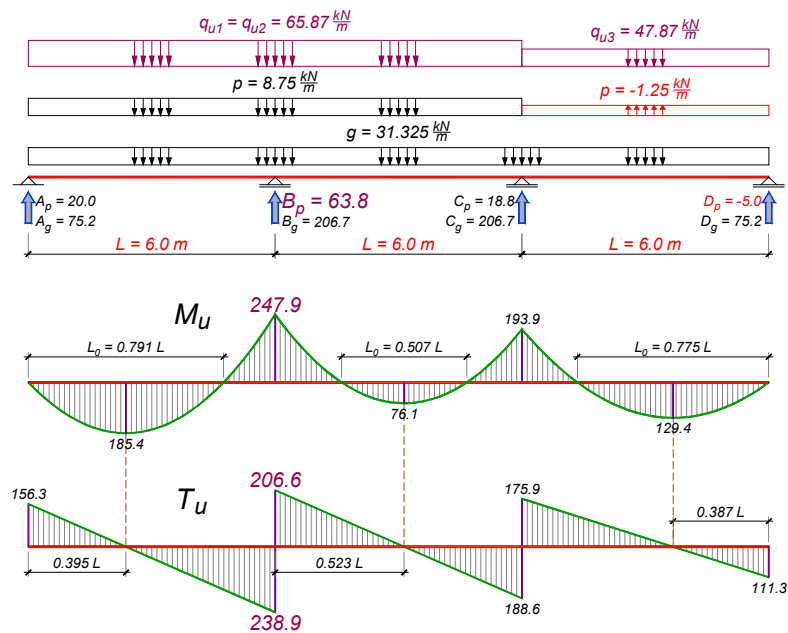
POS 2 - maksimalni moment nad osloncem

21



POS 2 - maksimalni moment nad osloncem

22



POS 2 - maksimalni moment nad osloncem

23

$$M_{1u} = -\left(\frac{q_{u1}}{15} + \frac{q_{u2}}{20} - \frac{q_{u3}}{60}\right) \times L_1^2 = -\left(\frac{65.87}{15} + \frac{65.87}{20} - \frac{47.87}{60}\right) \times 6.0^2 = -247.9 \text{ kNm}$$

$$M_{2u} = -\left(\frac{q_{u3}}{15} + \frac{q_{u2}}{20} - \frac{q_{u1}}{60}\right) \times L_1^2 = -\left(\frac{47.87}{15} + \frac{65.87}{20} - \frac{65.87}{60}\right) \times 6.0^2 = -193.9 \text{ kNm}$$

Maksimalna reakcija oslonca B usled povremenog opterećenja:

$$M_{1p} = -\left(\frac{8.75}{15} + \frac{8.75}{20} - \frac{-1.25}{60}\right) \times 6.0^2 = -37.5 \text{ kNm} \Rightarrow A_p = \frac{8.75 \times 6.0}{2} - \frac{37.5}{6.0} = 20 \text{ kN}$$

$$M_{2p} = -\left(\frac{-1.25}{15} + \frac{8.75}{20} - \frac{8.75}{60}\right) \times 6.0^2 = -7.5 \text{ kNm}$$

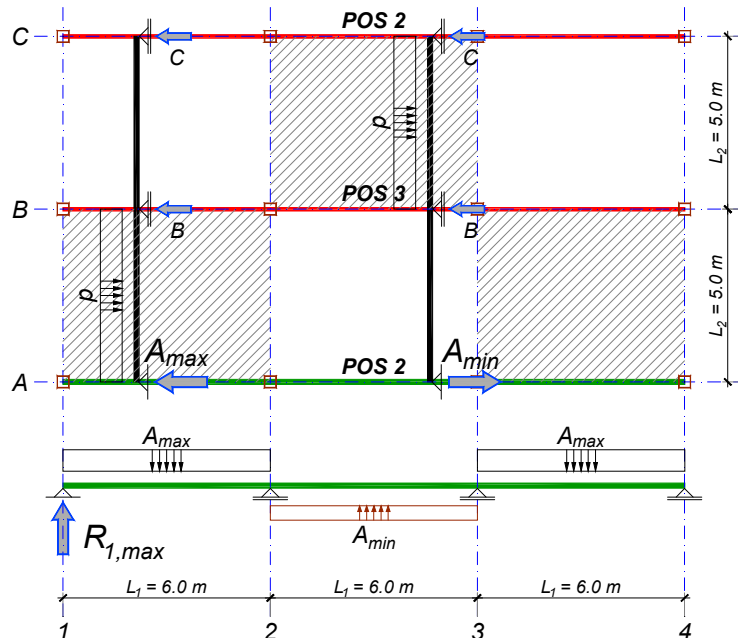
$$B_p = \frac{1}{6.0} \times \left(8.75 \times \frac{12.0^2}{2} - 7.5 - 20 \times 12.0\right) = 63.75 \text{ kN} = B_{p,max}$$

$$T_u^A = 1.6 \times 75.2 + 1.8 \times 20 = 156.3 \text{ kN} \Rightarrow T_u^{B,levo} = 156.3 - 65.87 \times 6.0 = -238.9 \text{ kN}$$

$$B_u = 1.6 \times 206.7 + 1.8 \times 63.75 = 445.5 \text{ kN} \Rightarrow T_u^{B,desno} = 445.5 - 238.9 = 206.6 \text{ kN}$$

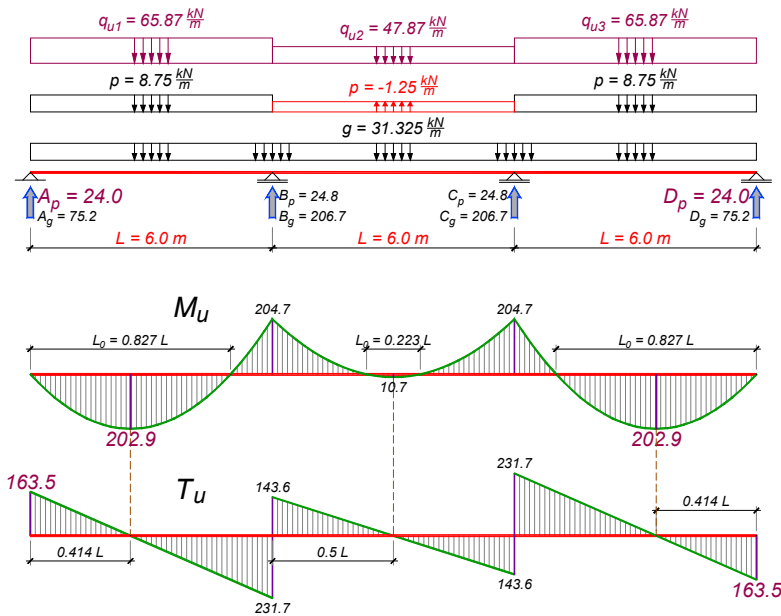
POS 2 - maksimalni moment u krajnjem polju

24



POS 2 - maksimalni moment u krajnjem polju

25



POS 2 - maksimalni moment u krajnjem polju

26

$$M_{1u} = -\left(\frac{65.87}{15} + \frac{47.87}{20} - \frac{65.87}{60}\right) \times 6.0^2 = -204.7 \text{ kNm} = M_{2u}$$

Maksimalna reakcija oslonca A usled povremenog opterećenja:

$$M_{1p} = -\left(\frac{8.75}{15} + \frac{-1.25}{20} - \frac{8.75}{60}\right) \times 6.0^2 = -13.5 \text{ kNm} = M_{1p}$$

$$A_p = \frac{8.75 \times 6.0}{2} - \frac{13.5}{6.0} = 24 \text{ kN} = A_{p,\max}$$

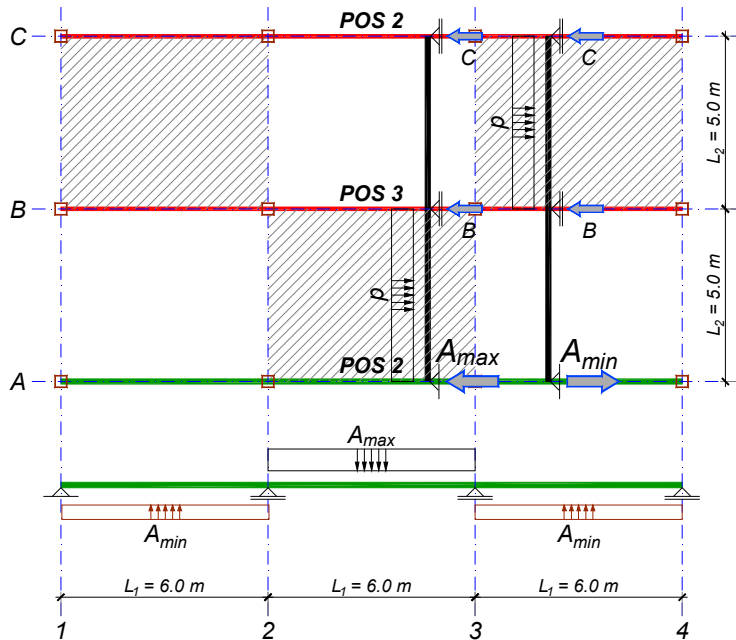
$$T_u^A = 1.6 \times 75.2 + 1.8 \times 24 = 163.5 \text{ kN} \Rightarrow x_{\max} = \frac{163.5}{65.87} = 2.48 \text{ m}$$

$$M_{u,\max}^{01} = 163.5 \times 2.48 - \frac{65.87 \times 2.48^2}{2} = 202.9 \text{ kNm}$$

$$L_0^{01} = 2x_{\max} = 2 \times 2.48 = 4.96 \text{ m} \Rightarrow B = \min \left\{ \begin{array}{l} 25 + 8 \times 14 = 137 \\ 25 + \frac{0.25}{3} \times 496 = 66 \end{array} \right\} = 66 \text{ cm}$$

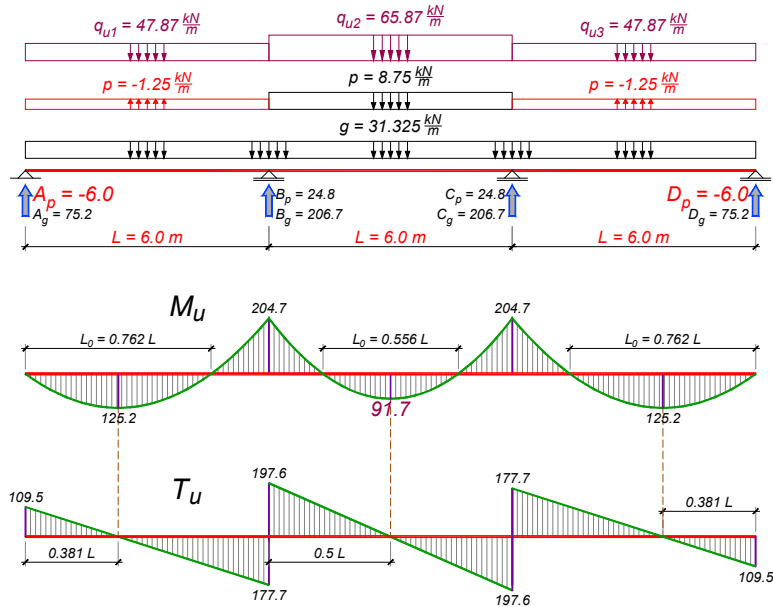
POS 2 - maksimalni moment u srednjem polju

27



POS 2 - maksimalni moment u srednjem polju

28



POS 2 - maksimalni moment u srednjem polju

29

$$M_{1u} = -\left(\frac{47.87}{15} + \frac{65.87}{20} - \frac{47.87}{60}\right) \times 6.0^2 = -204.7 \text{ kNm} = M_{2u}$$

$$M_{1p} = -\left(\frac{-1.25}{15} + \frac{8.75}{20} - \frac{-1.25}{60}\right) \times 6.0^2 = -13.5 \text{ kNm} = M_{2p}$$

$$A_p = \frac{-1.25 \times 6.0}{2} - \frac{13.5}{6.0} = -6 \text{ kN} = A_{p,\min}$$

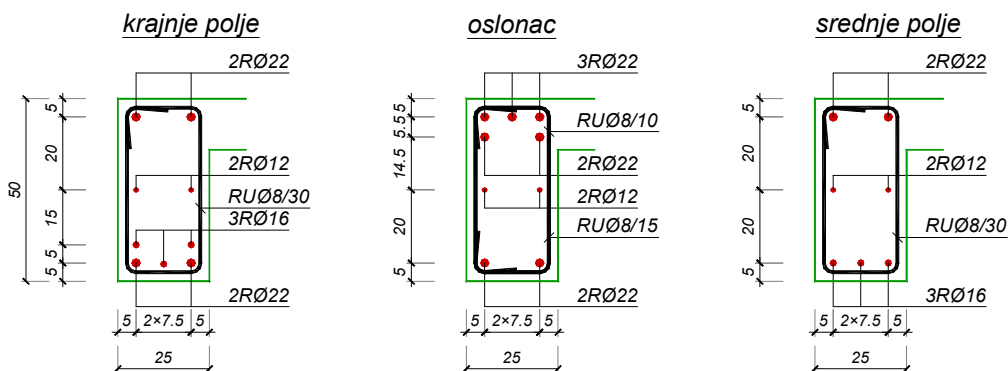
$$M_{u,\max}^{12} = \frac{65.87 \times 6.0^2}{8} + M_{1u} = 296.4 - 204.7 = 91.7 \text{ kNm}$$

$$L_0^{12} = L \sqrt{\frac{M_{u,\max}^{12}}{f}} = 6.0 \times \sqrt{\frac{91.7}{296.4}} = 3.34 \text{ m} = \sqrt{\frac{8 \times M_{u,\max}^{12}}{q_u}}$$

$$B = \min \left\{ \begin{array}{l} 25 + 8 \times 14 = 137 \\ 25 + \frac{0.25}{3} \times 334 = 52.8 \end{array} \right\} = 52.8 \text{ cm}$$

POS 2 – karakteristični preseci

30



Proračun sila u stubovima

31

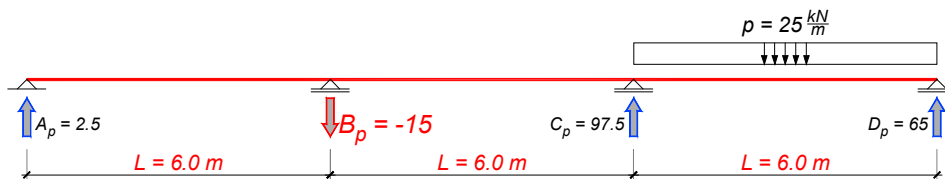
4.1 STUBOVI POS S1

Srednja dva, nazvani po osama u kojima se nalaze: 2B i 3B. Prihvataju srednje reakcije greda POS 3:

$$G^{S1} = B_g^{POS3} = 280.5 \text{ kN}$$

$$P_{\max}^{S1} = B_{p,\max}^{POS3} = 180.0 \text{ kN (tačka 2.3.1)}$$

Minimalna sila usled povremenog opterećenja u ovom stubu će se javiti u slučaju da se maksimalno opterećenje nađe u trećem polju (odnosno, u prvom polju za stub C):



$$M_{1p} = \frac{25}{60} \times 6.0^2 = 15 \text{ kNm} \Rightarrow A_p = \frac{15}{6.0} = 2.5 \text{ kN}$$

$$M_{2p} = -\frac{25}{15} \times 6.0^2 = -60 \text{ kNm} \Rightarrow B_p = \frac{1}{6.0} \times (-60 - 2.5 \times 12.0) = -15 \text{ kN}$$

$$P_{\min}^{S1} = B_{p,\min}^{POS3} = -15 \text{ kN}$$

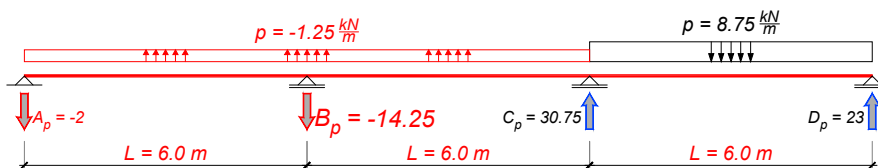
STUBOVI POS S3

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Četiri ivična stuba, nazvani po osama u kojima se nalaze: 2A, 2C, 3A i 3C. Prihvataju srednje reakcije greda POS 2:

$$G^{S3} = B_g^{POS2} = 206.7 \text{ kN}$$

$$P_{\max}^{S3} = B_{p,\max}^{POS2} = 63.75 \text{ kN (tačka 3.3.1)}$$



$$M_{1p} = \left(\frac{-1.25}{15} + \frac{-1.25}{20} - \frac{8.75}{60} \right) \times 6.0^2 = 10.5 \text{ kNm} \Rightarrow A_p = \frac{-1.25 \times 6.0}{2} + \frac{10.5}{6.0} = -2.0 \text{ kN}$$

$$M_{2p} = \left(\frac{8.75}{15} + \frac{-1.25}{20} - \frac{-1.25}{60} \right) \times 6.0^2 = -19.5 \text{ kNm}$$

$$B_{p,\min} = \frac{1}{6.0} \times \left(\frac{-1.25 \times 12.0^2}{2} - 19.5 + 2.0 \times 12.0 \right) = -14.25 \text{ kN}$$

$$P_{\min}^{S3} = B_{p,\min}^{POS2} = -14.25 \text{ kN}$$

STUBOVI POS S2

Dva ivična stuba, nazvani po osama u kojima se nalaze: 1B i 4B. Prihvataju krajnje reakcije greda POS 3 i pripadajući deo fasade u osama 1 i 4:

$$B_F = 1.25 \times 16.95 \times 5.0 = 105.9 \text{ kN}$$

$$G^{S2} = A_g^{POS3} + B_F = 102.0 + 105.9 = 207.9 \text{ kN}$$

$$P_{\max}^{S2} = A_{p,\max}^{POS3} = 67.5 \text{ kN (tačka 2.3.2.1)}$$

$$P_{\min}^{S2} = A_{p,\min}^{POS3} = -7.5 \text{ kN (tačka 2.3.3.1)}$$

STUBOVI POS S4

Četiri ugaona stuba, nazvani po osama u kojima se nalaze: 1A, 1C, 4A i 4C. Prihvataju krajnje reakcije greda POS 2 i pripadajući deo fasade u osama 1 i 4:

$$A_F = 0.375 \times 16.95 \times 5.0 = 31.8 \text{ kN}$$

$$G^{S4} = A_g^{POS2} + A_F = 75.2 + 31.8 = 107.0 \text{ kN}$$

$$P_{\max}^{S4} = A_{p,\max}^{POS2} = 24 \text{ kN (tačka 3.3.2.1)}$$

$$P_{\min}^{S4} = A_{p,\min}^{POS2} = -6 \text{ kN (tačka 3.3.3.1)}$$

POS 3, POS 2 – poređenje uticaja