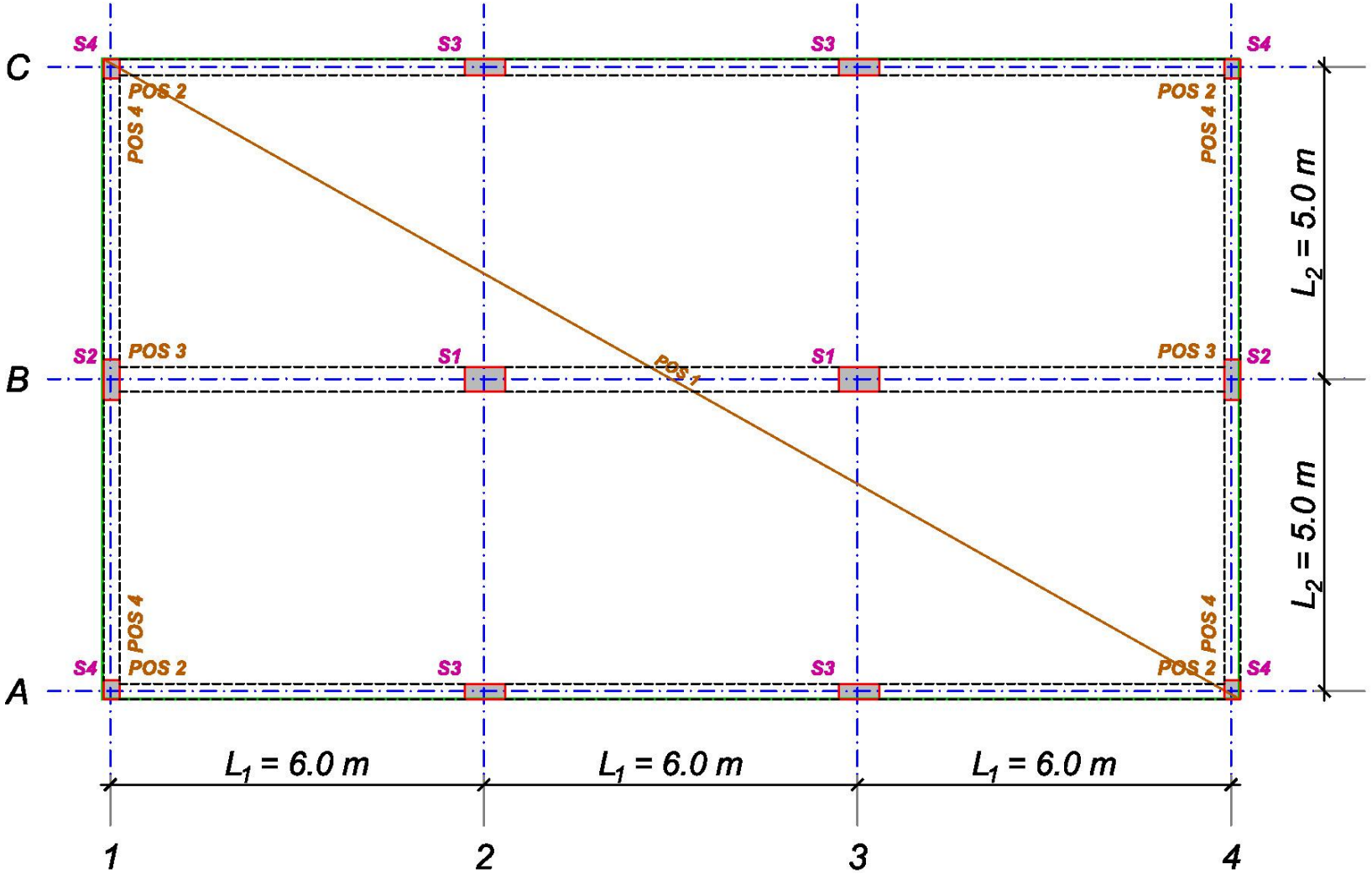
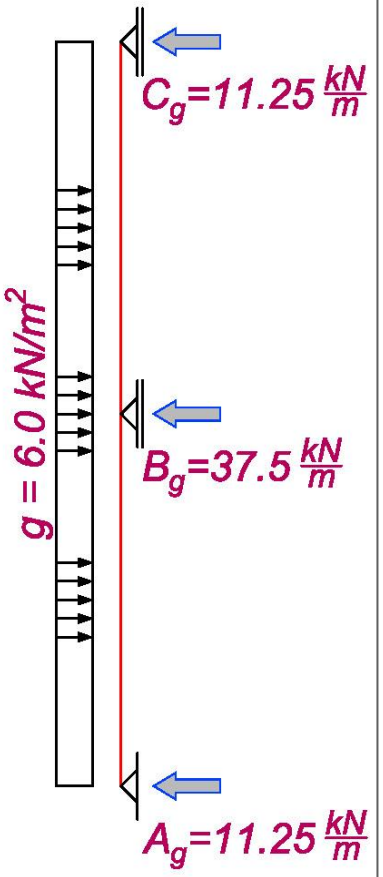
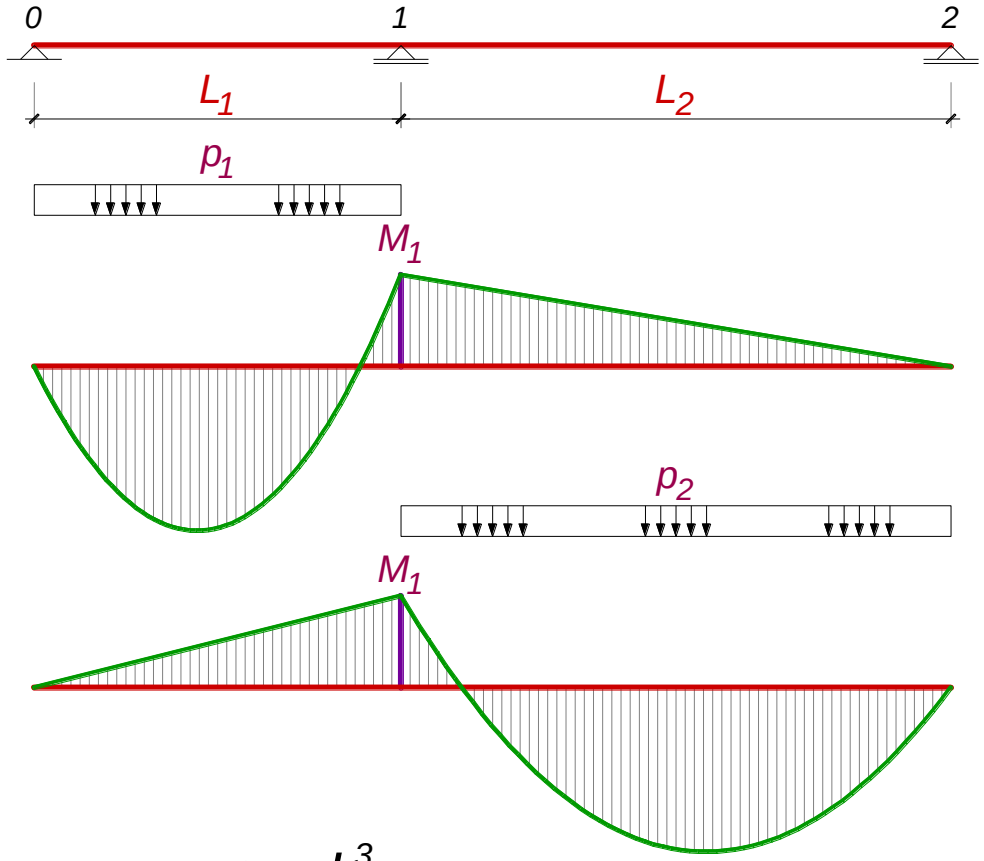
Ploča POS 1 – stalno opterećenje





Kontinualni nosač preko dva polja



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

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

	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

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_{q1} i minimalna reakcija C_{q1}. Nepoznata vrednost oslonačkog momenta savijanja je:

$$M_{q1} = -\frac{q_1 L_1^3}{8(L_1 + L_2)} = -\frac{q_1 L^2}{16} = -\frac{4.0 \times 5.0^2}{16} = -6.25 \frac{kNm}{m}$$

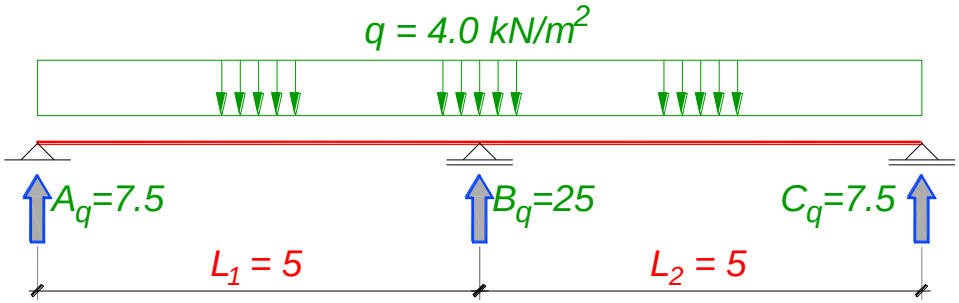
dok su odgovarajuće reakcije krajnjih oslonaca:

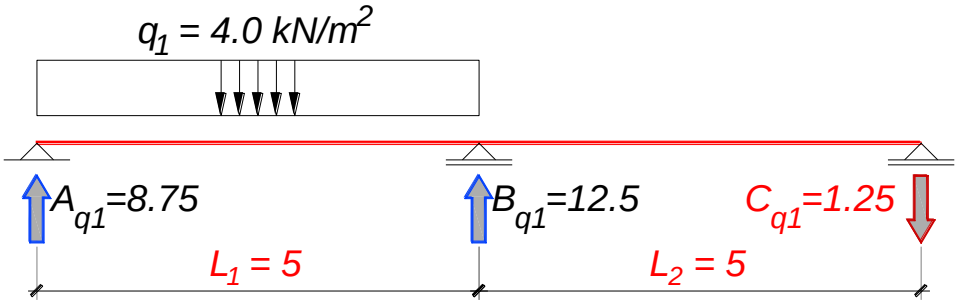
$$A_{q1} = \frac{q_1 L_1}{2} + \frac{M_{q1}}{L_1} = \frac{q_1 L}{2} - \frac{q_1 L^2}{16 L_1} = \frac{7}{16} q_1 L = \frac{7}{16} \times 4.0 \times 5.0 = 8.75 \frac{kN}{m} = A_{q,max}$$

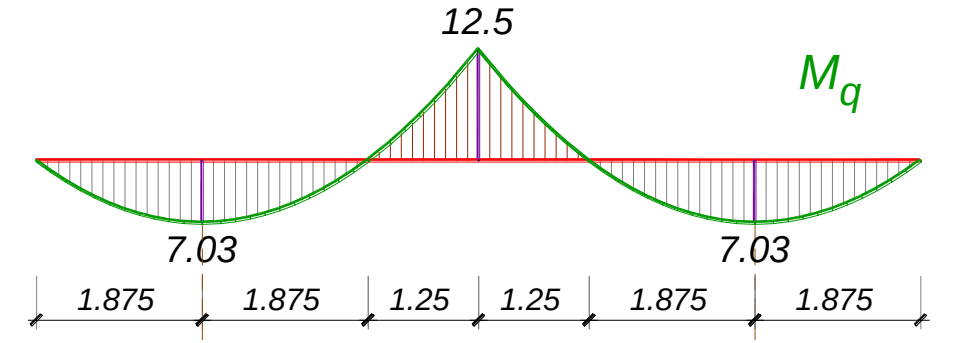
$$C_{q1} = \frac{M_1}{L_2} = -\frac{q_1 L^2}{16 L_2} = -\frac{q_1 L}{16} = -\frac{4.0 \times 5.0}{16} = -1.25 \frac{kN}{m} = C_{q,min}$$

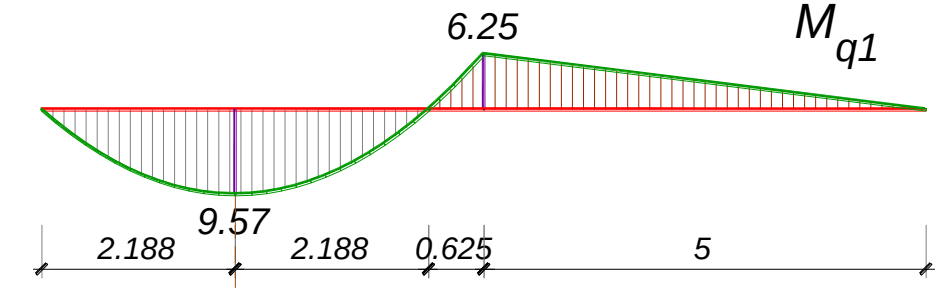
Na narednoj skici su prikazani dijagrami presečnih sila i reakcije oslonaca usled povremenog opterećenja koje deluje po čitavoj ploči, odnosno samo u prvom polju.

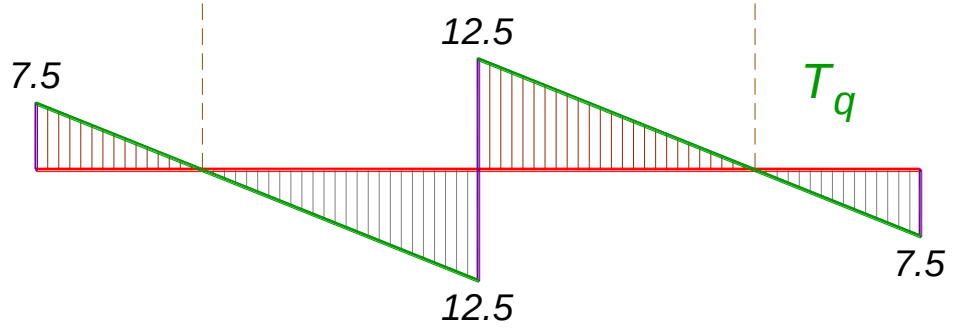
Ploča POS 1 – položaji povremenog opterećenja

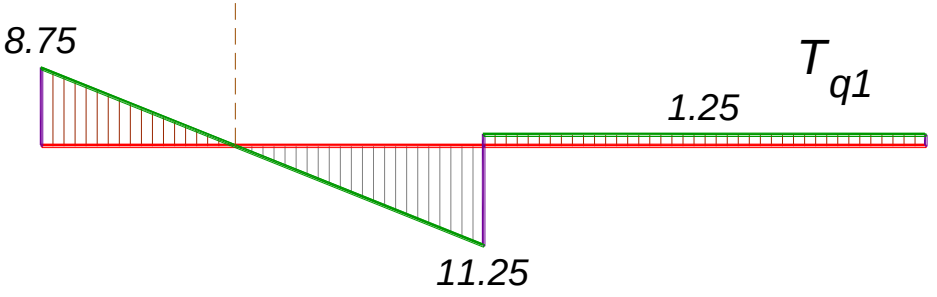




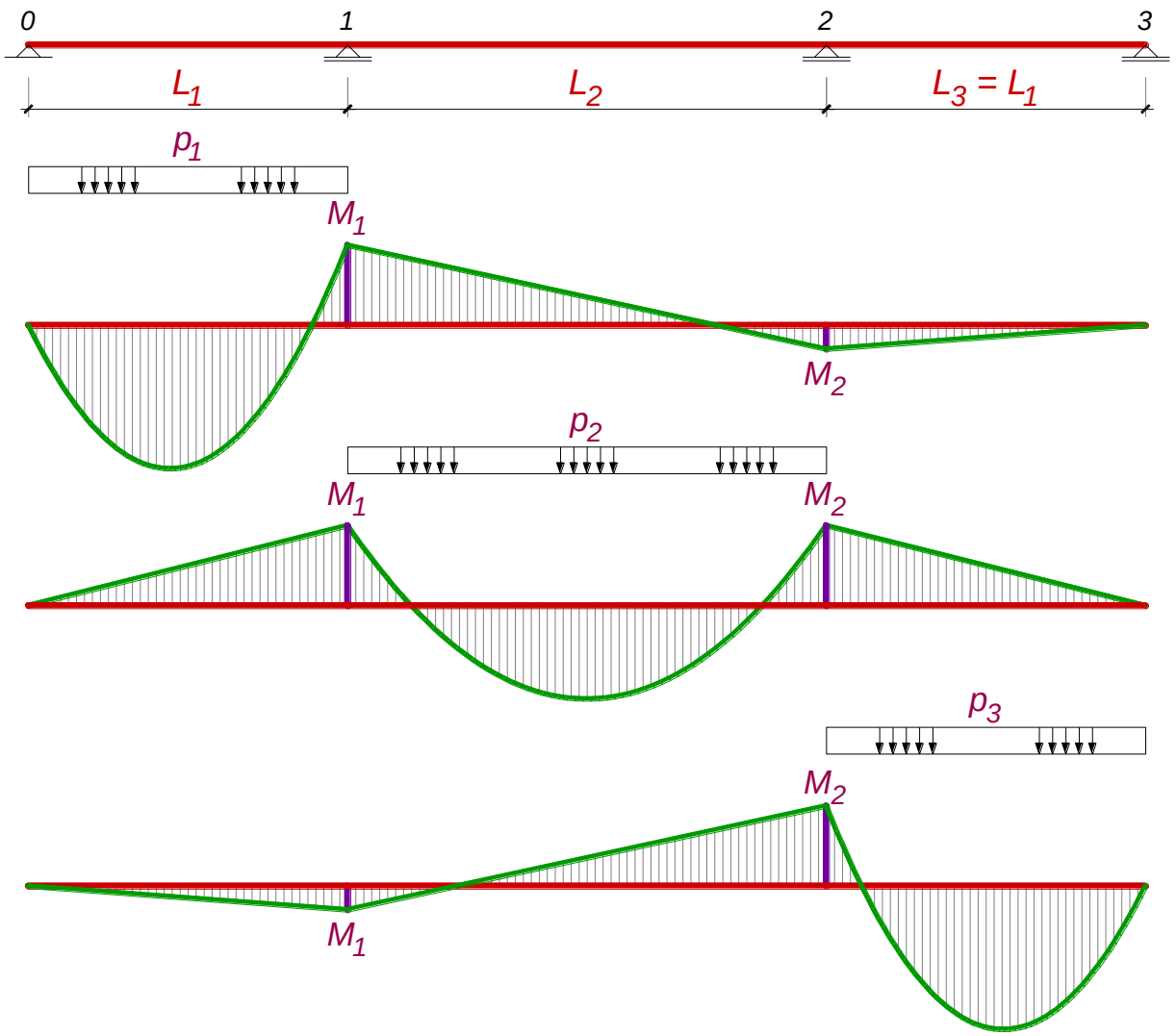






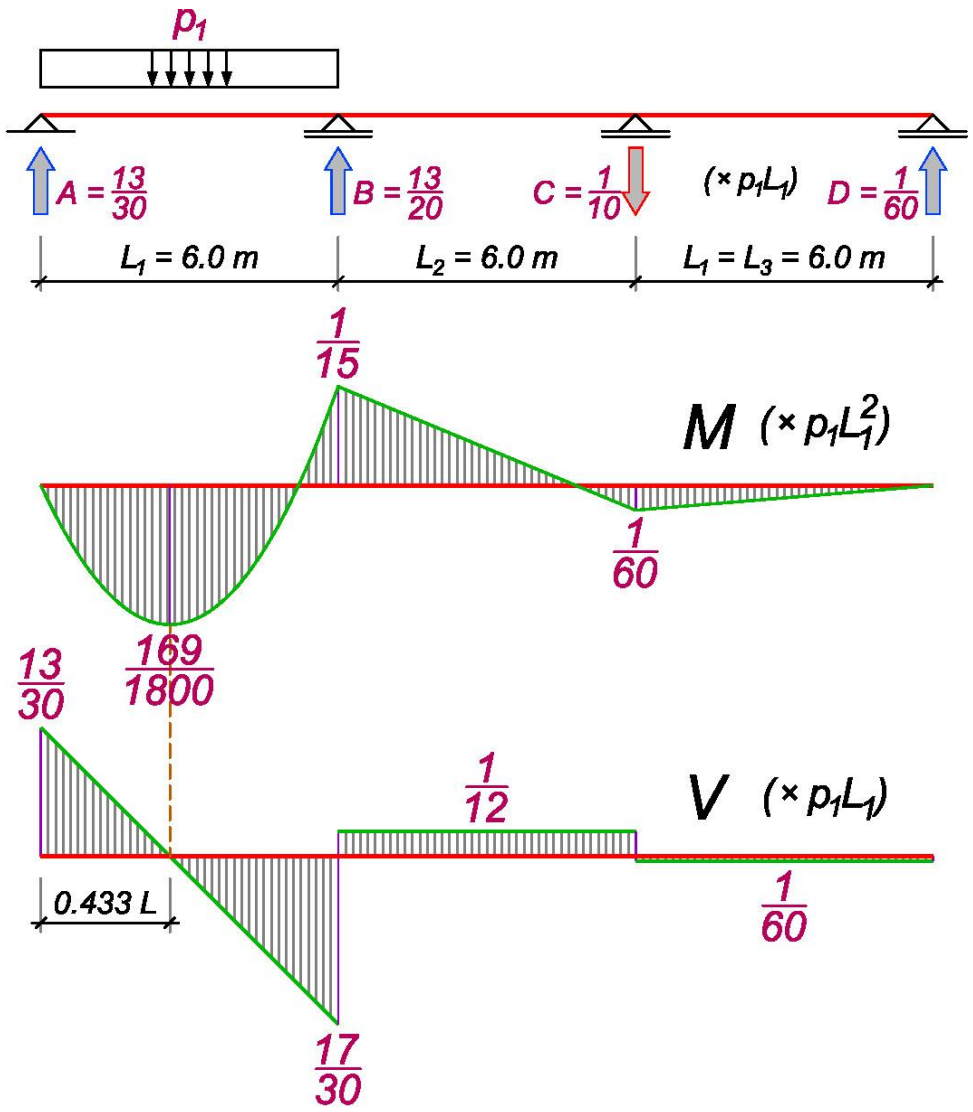


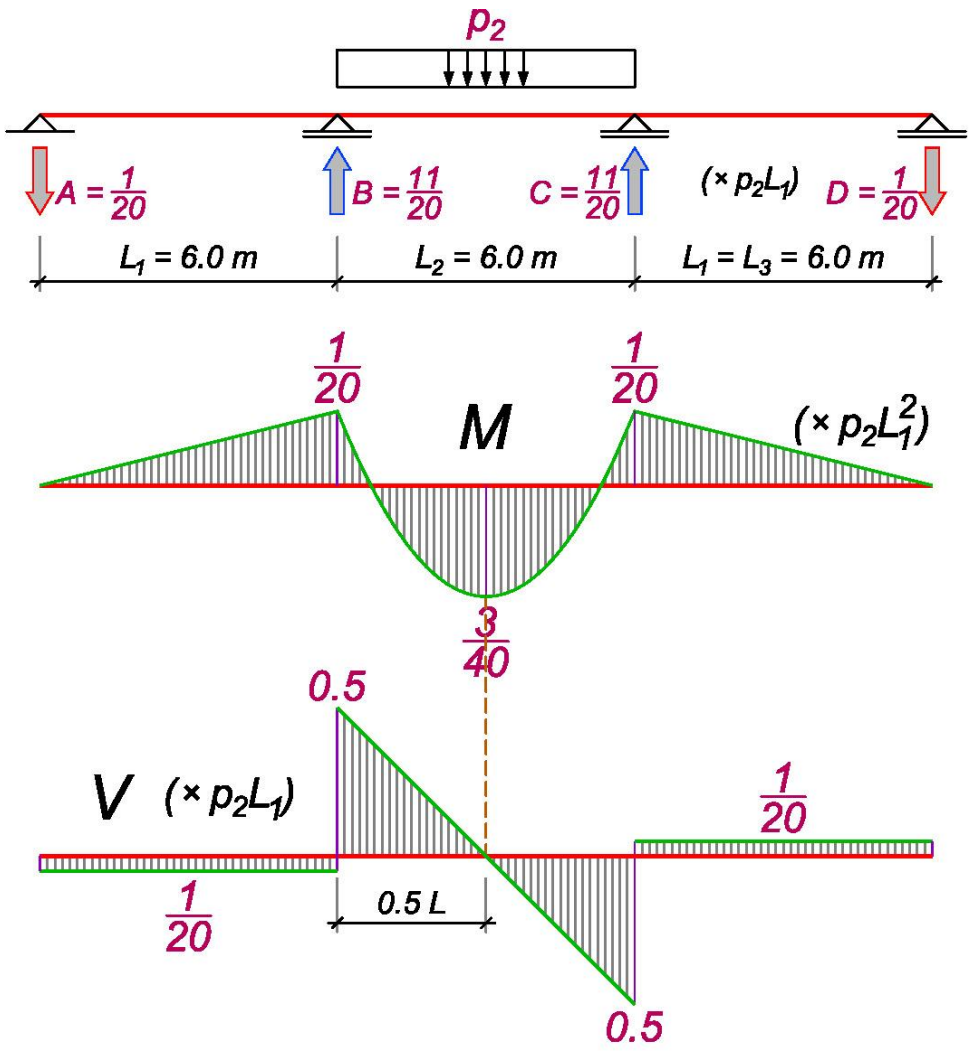
Kontinualni nosač preko tri polja



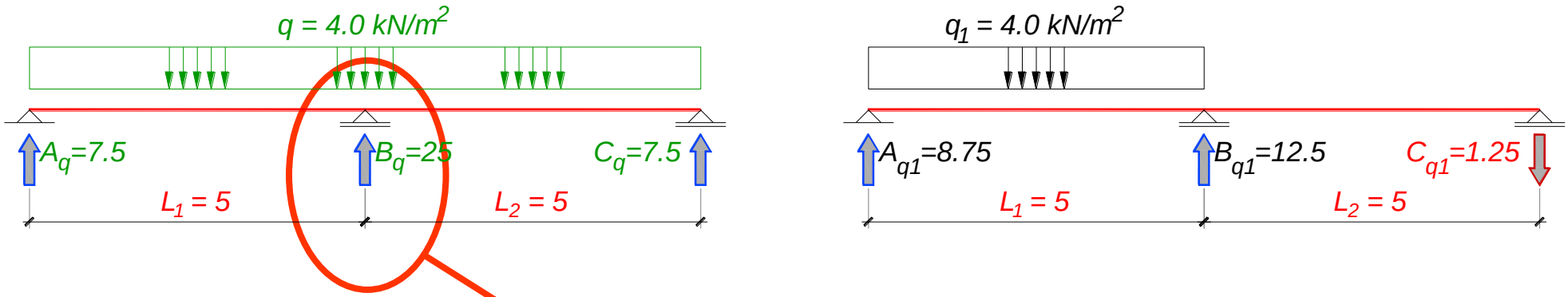
	opterećeno polje		
L_2/L_1	p_1	p_2	p_3
0.5	-0.0857	-0.0089	0.0143
0.6	-0.0810	-0.0142	0.0152
0.7	-0.0768	-0.0209	0.0158
0.8	-0.0731	-0.0291	0.0162
0.9	-0.0697	-0.0388	0.0165
1	**-0.0667**	**-0.0500**	**0.0167**
1.1	-0.0639	-0.0628	0.0167
1.2	-0.0614	-0.0771	0.0167
	$\times pL_1^2$	$\times pL_1^2$	$\times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

Kontinualni nosač preko tri polja





Srednja greda – POS 3



2.2 ANALIZA OPTEREĆENJA ZA POS 3

Stalno opterećenje je sračunato u primeru P7:

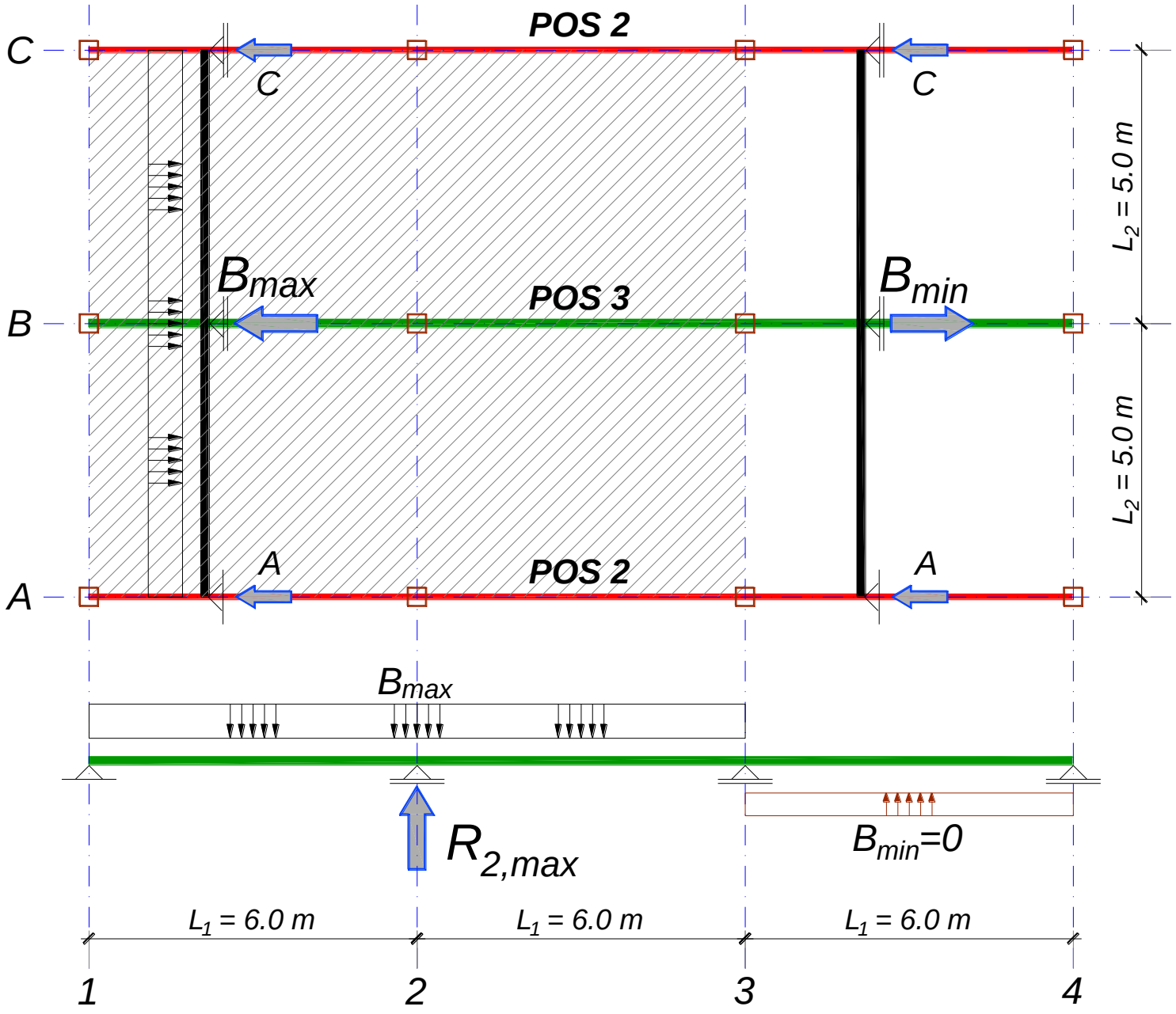
ukupno, stalno opterećenje g = 42.5 kN/m

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:

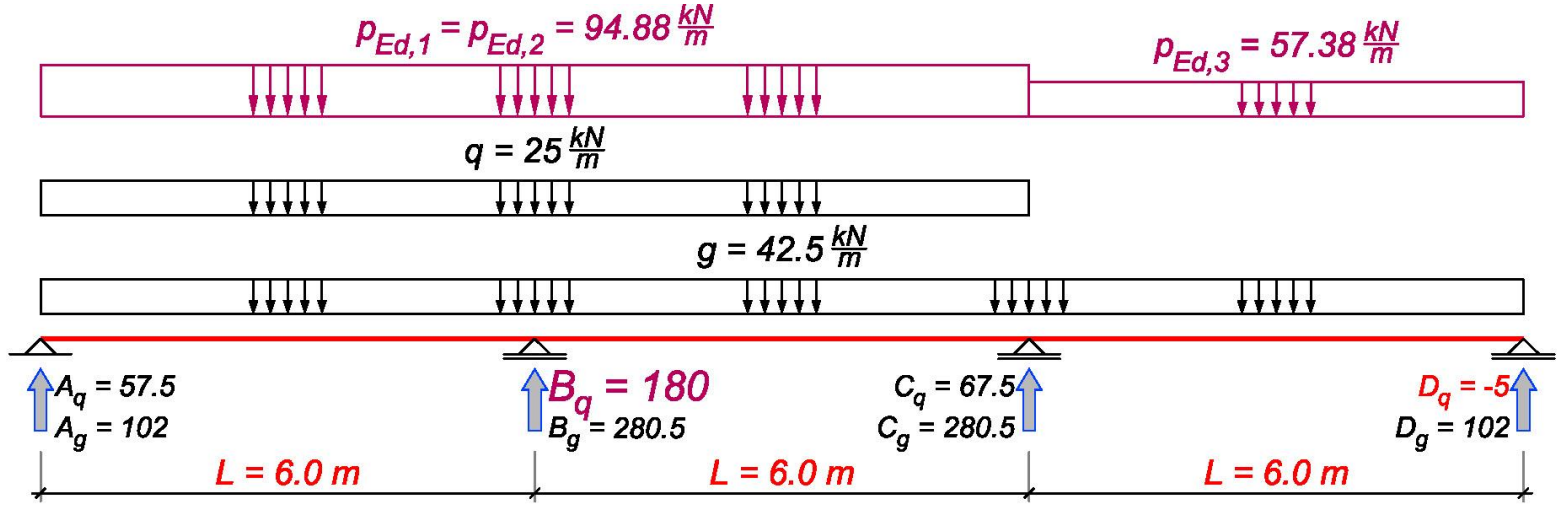
povremeno opterećenje od POS 1: $B_{q,max} = q_{max}$ = 25.0 kN/m

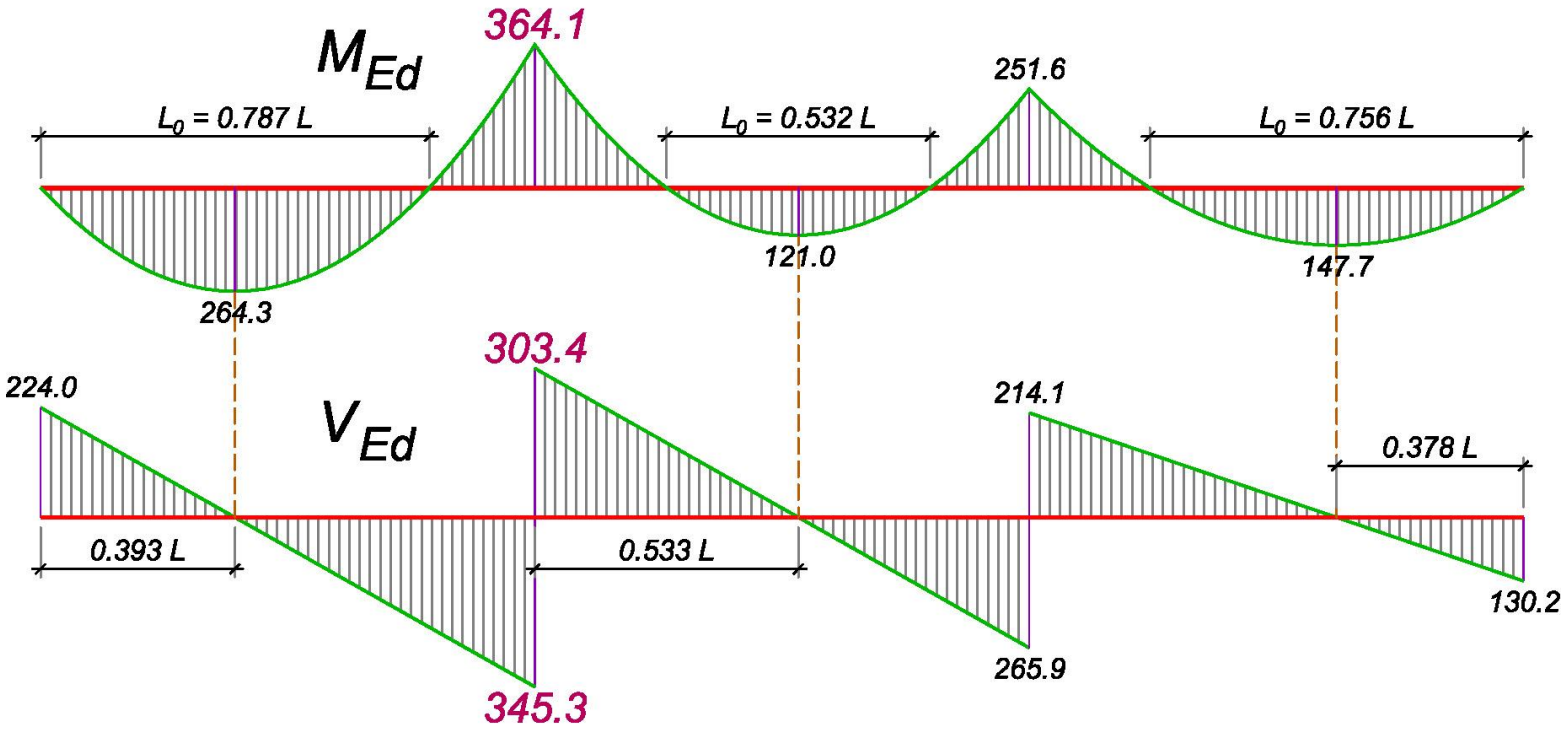
povremeno opterećenje od POS 1: $B_{q,min} = q_{min}$ = 0

POS 3 - maksimalni moment nad osloncem



POS 3 - maksimalni moment nad osloncem





2.3.1 Presek nad srednjim osloncem

$p_{Ed,\max} = 1.35\times 42.5 + 1.5\times 25.0 = 94.88\ kN/m = p_{Ed,1} = p_{Ed,2}$

$p_{Ed,\min} = 1.35\times 42.5 = 57.38\ kN/m = p_{Ed,3}$

$$M_{1,Ed} = -\left(\frac{p_{Ed,1}}{15} + \frac{p_{Ed,2}}{20} - \frac{p_{Ed,3}}{60}\right)\times L_1^2 = -\left(\frac{94.88}{15} + \frac{94.88}{20} - \frac{57.38}{60}\right)\times 6.0^2 = -364.1\,kNm$$

$$M_{2,Ed} = -\left(\frac{p_{Ed,3}}{15} + \frac{p_{Ed,2}}{20} - \frac{p_{Ed,1}}{60}\right)\times L_1^2 = -\left(\frac{57.38}{15} + \frac{94.88}{20} - \frac{94.88}{60}\right)\times 6.0^2 = -251.6\,kNm$$

Maksimalna reakcija oslonca B usled povremenog opterećenja:

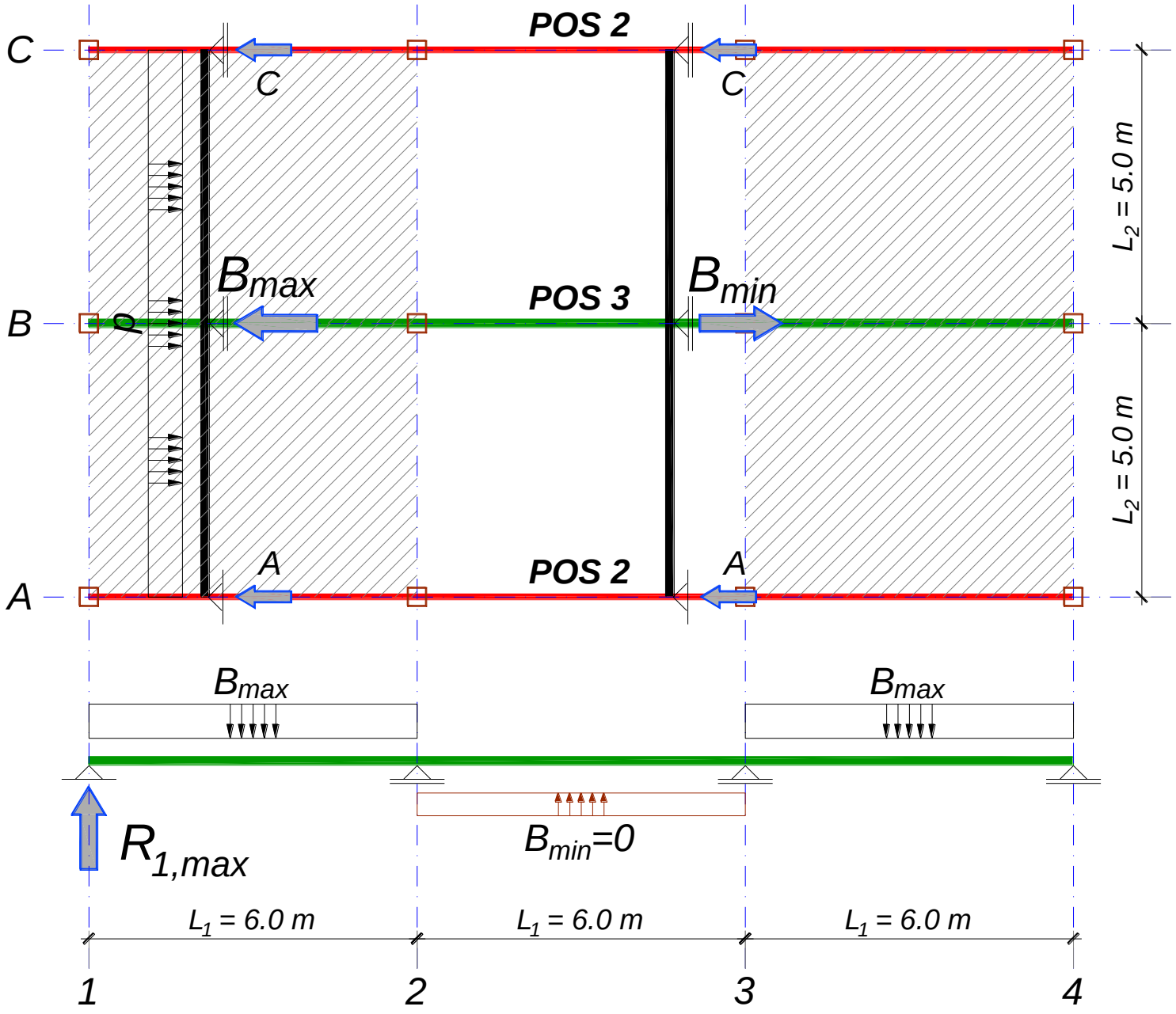
$$M_{1q} = -\left(\frac{25}{15} + \frac{25}{20}\right)\times 6.0^2 = -105\,kNm \Rightarrow A_q = \frac{25\times 6.0}{2} - \frac{105}{6.0} = 57.5\,kN$$

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

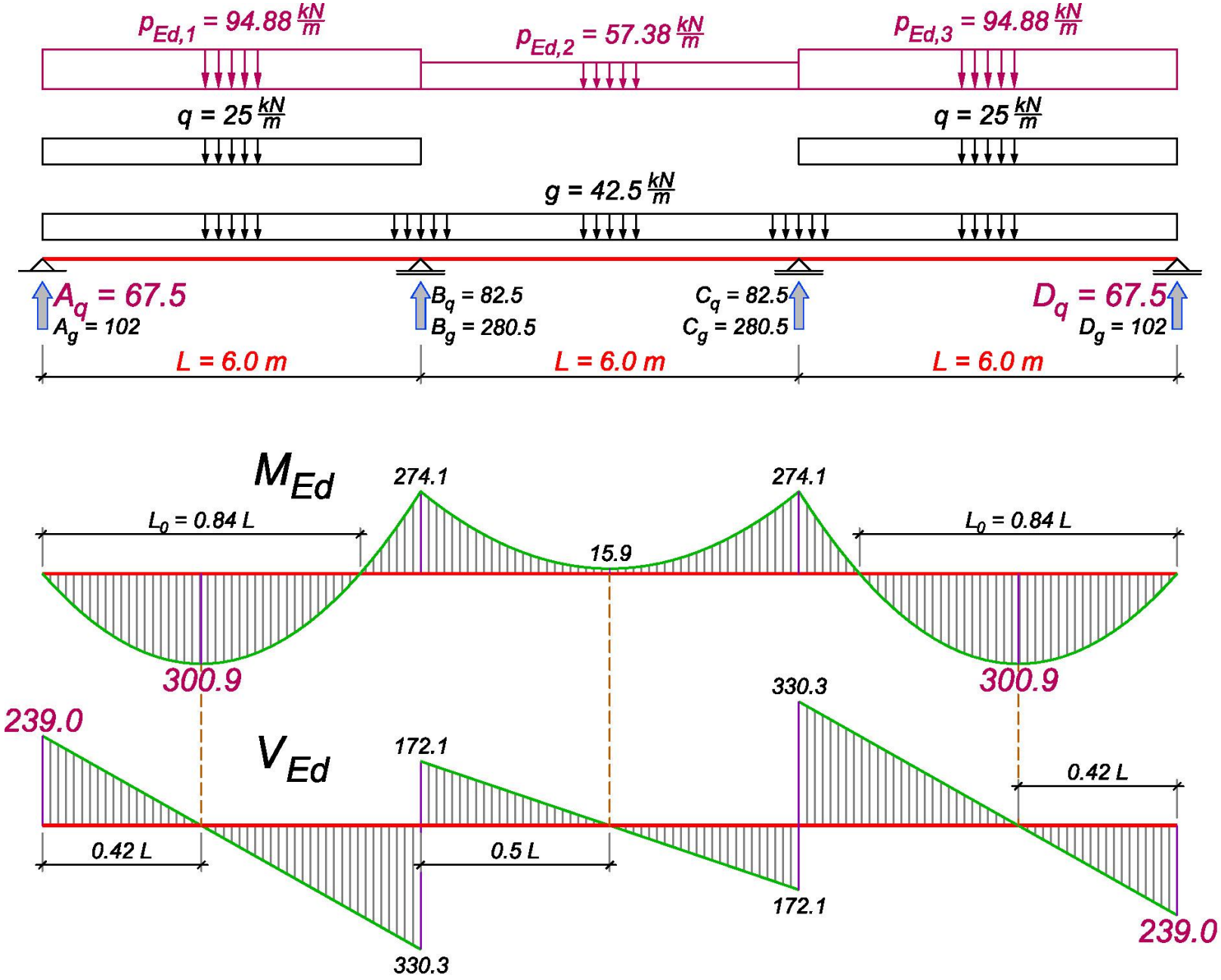
$$V_{Ed}^{A} = 1.35\times 102 + 1.5\times 57.5 = 224.0\,kN \Rightarrow V_{Ed}^{B,levo} = 224.0 - 94.88\times 6.0 = -345.3\,kN$$

$$B_{Ed} = 1.35\times 280.5 + 1.5\times 180 = 648.7\,kN \Rightarrow V_{Ed}^{B,desno} = 648.7 - 345.3 = 303.4\,kN$$

POS 3 - maksimalni moment u krajnjem polju



POS 3 - maksimalni moment u krajnjem polju



POS 3 - maksimalni moment u krajnjem polju

2.3.2 Preseci u krajnjim poljima

Kao što je pokazano u tački 2.1, potrebno je u krajnja polja naneti maksimalne, a u srednje polje mininalnu reakciju usled povremenog opterećenja sa ploče.

$$M_{1,Ed} = -\left(\frac{94.88}{15} + \frac{57.38}{20} - \frac{94.88}{60}\right) \times 6.0^2 = -274.1\,kNm = M_{2,Ed}$$

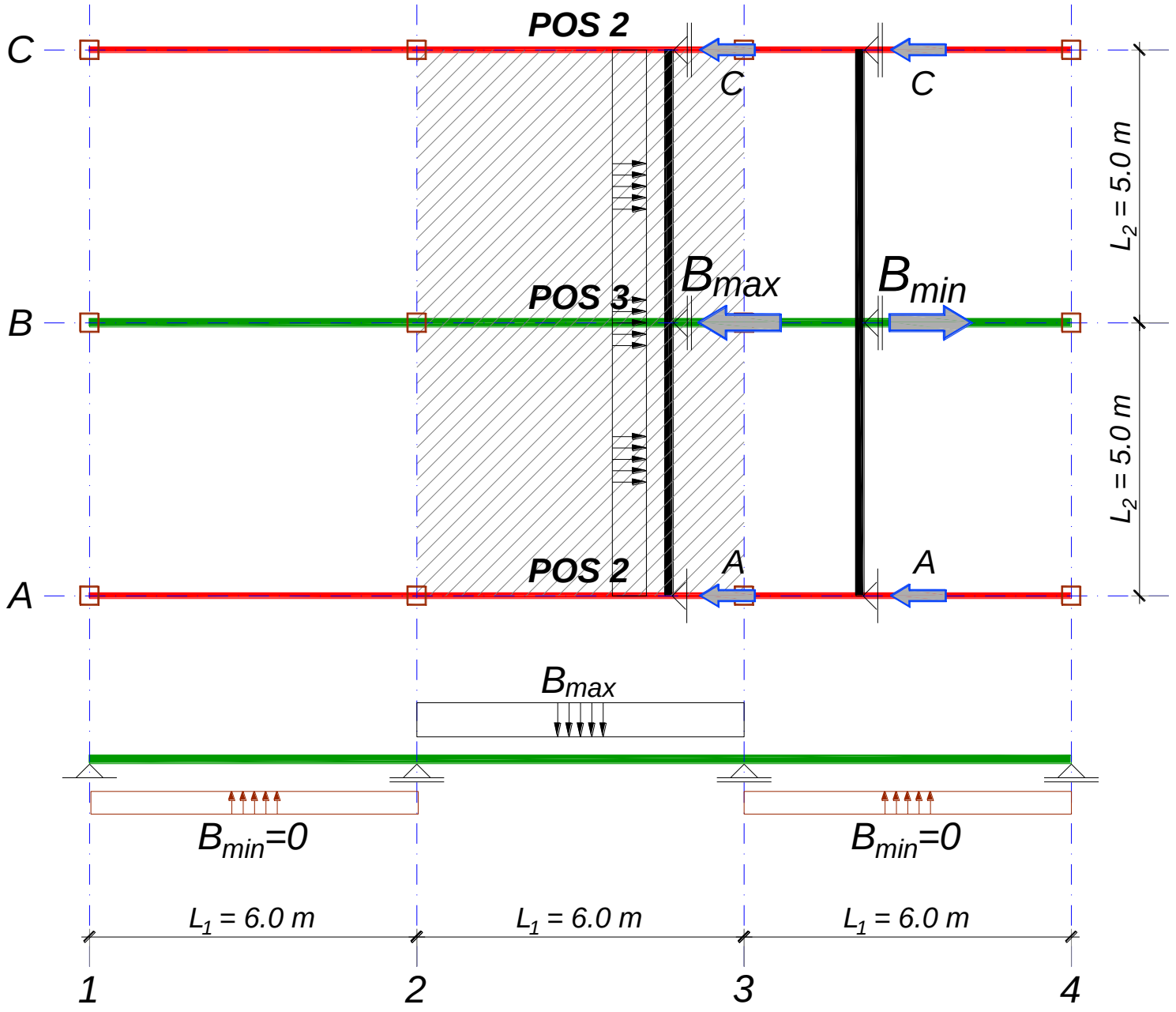
Maksimalna reakcija oslonca A usled povremenog opterećenja:

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

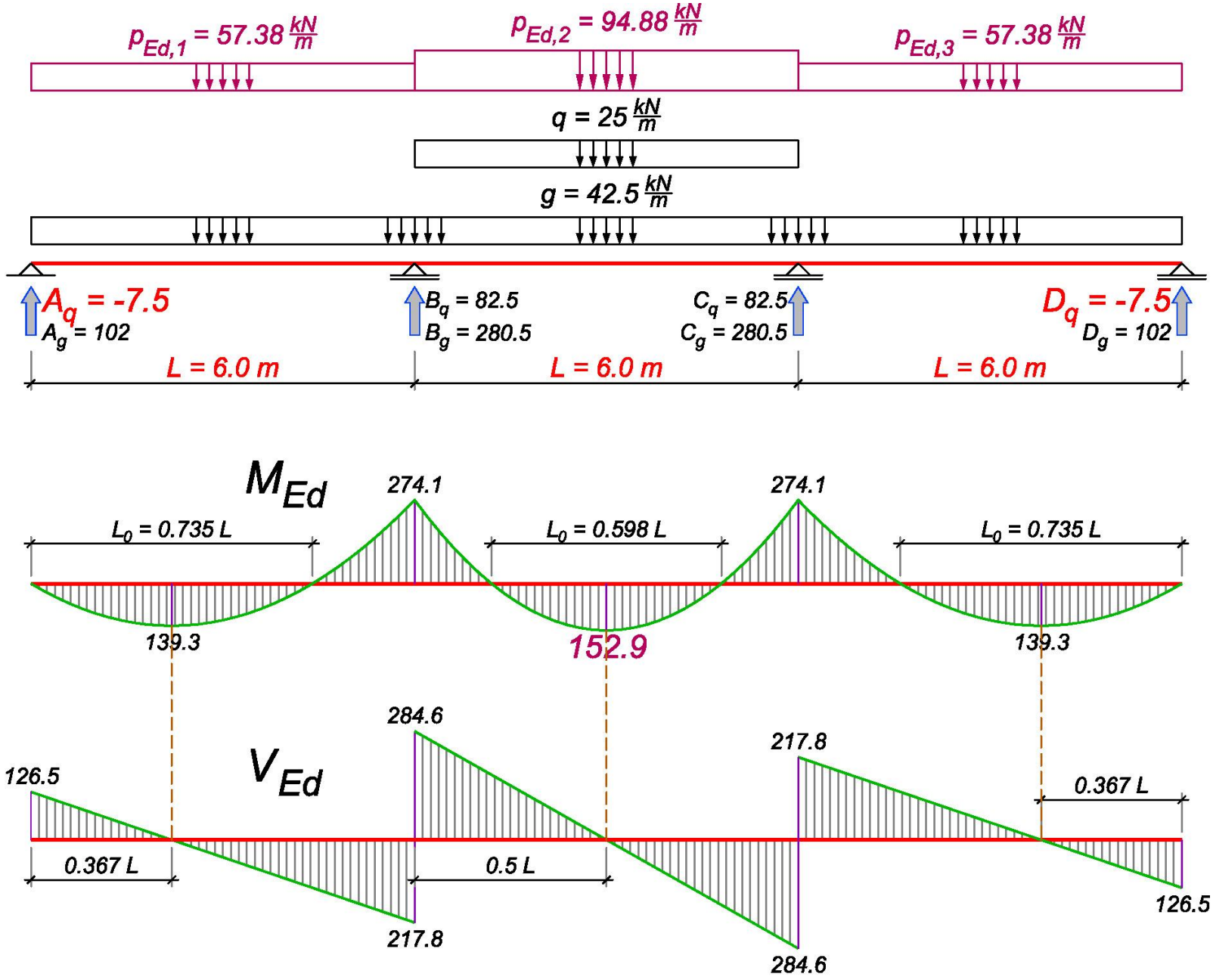
$$V_{Ed}^{A} = 1.35 \times 102 + 1.5 \times 67.5 = 239.0\,kN \Rightarrow x_{max} = \frac{239.0}{94.88} = 2.52\,m$$

$$M_{Ed,max}^{01} = 239.0 \times 2.52 - \frac{94.88 \times 2.52^2}{2} = 300.9\,kNm$$

POS 3 - maksimalni moment u srednjem polju



POS 3 - maksimalni moment u srednjem polju



2.3.3 Presek u srednjem polju

Kao što je pokazano u tački 2.1, potrebno je u krajnja polja naneti minimalne, a u srednje polje maksimalnu reakciju usled povremenog opterećenja sa ploče.

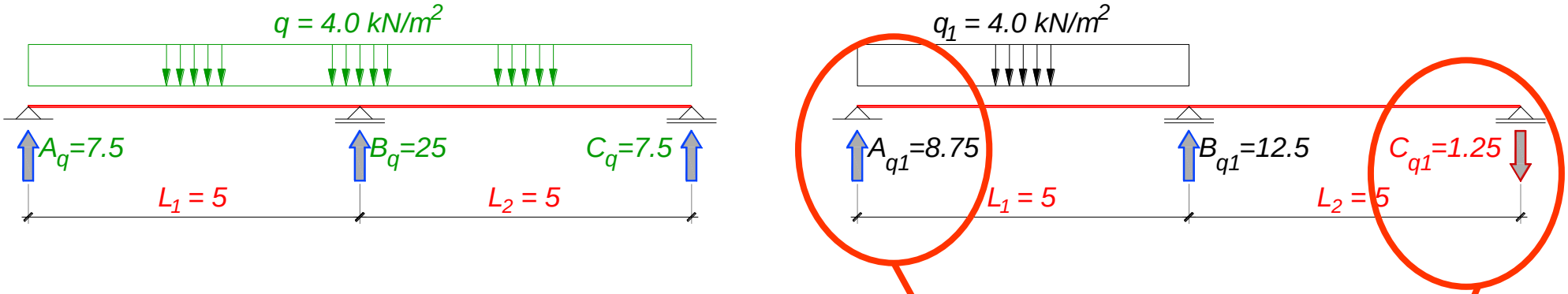
$$M_{1,Ed} = -\left(\frac{57.38}{15} + \frac{94.88}{20} - \frac{57.38}{60}\right) \times 6.0^2 = -274.1\,kNm = M_{2,Ed}$$

$$M_{1q} = -\frac{25}{20} \times 6.0^2 = -45\,kNm \Rightarrow A_q = -\frac{45}{6.0} = -7.5\,kN = A_{q,min}$$

$$M_{Ed,max}^{12} = \frac{94.88 \times 6.0^2}{8} - 274.1 = 152.9\,kNm$$

$$L_0^{12} = \sqrt{\frac{8 \times M_{Ed,max}^{12}}{p_{Ed,2}}} = \sqrt{\frac{8 \times 152.9}{94.88}} = 3.59\,m$$

Ivična greda – POS 2



3.2 ANALIZA OPTEREĆENJA ZA POS 2

Stalno opterećenje je sračunato u primeru P1:

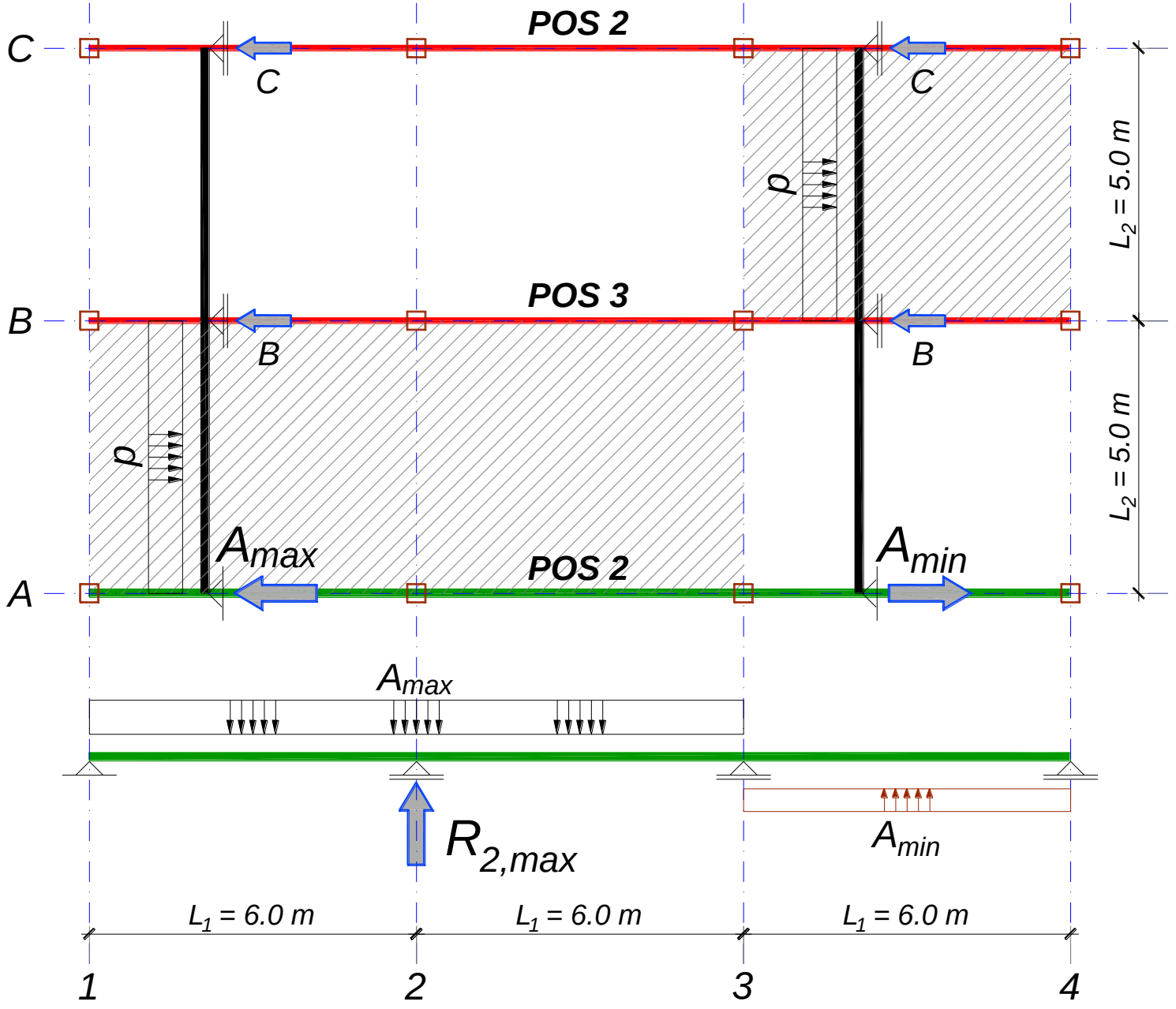
ukupno, stalno opterećenje g = 27.94 kN/m

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

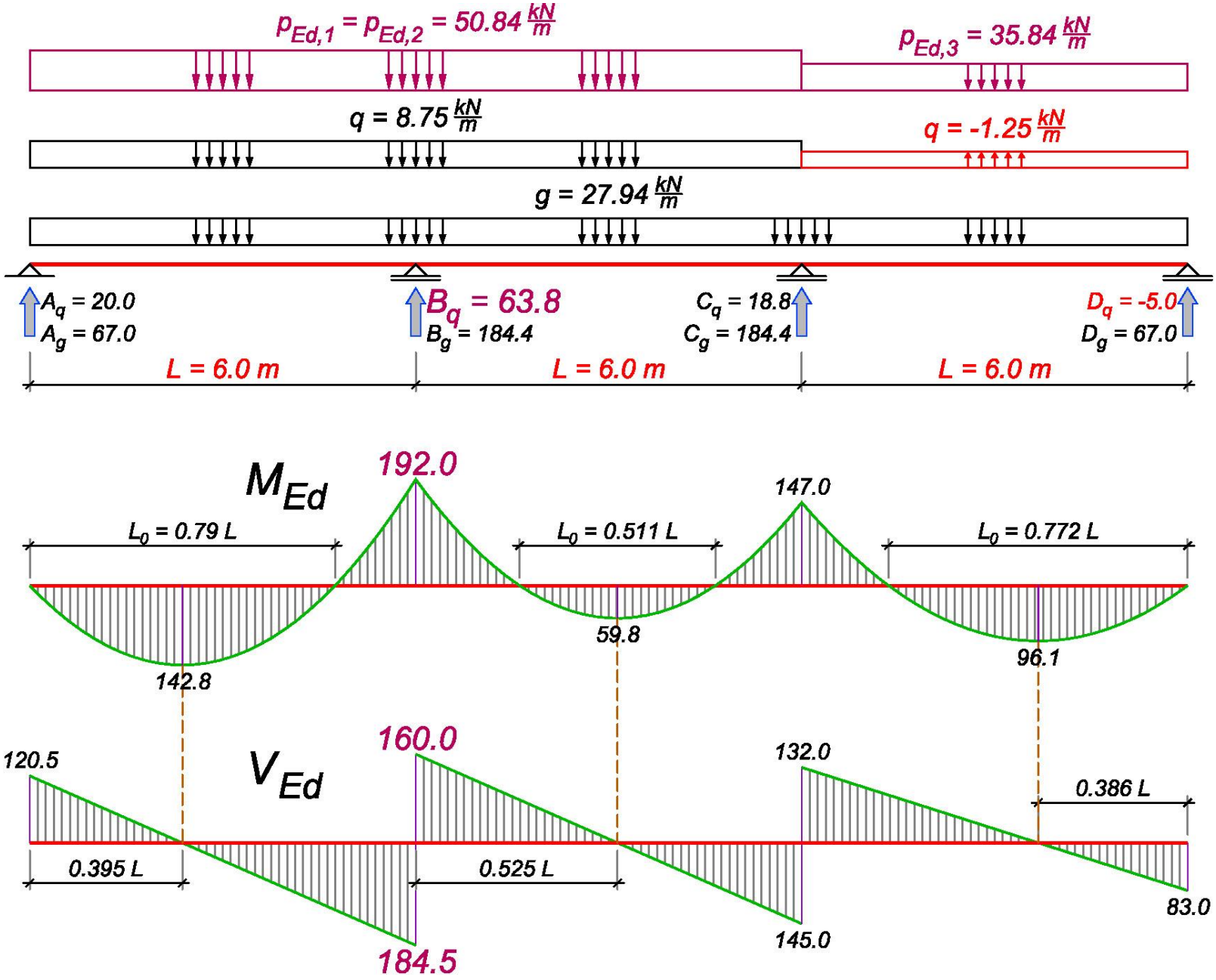
povremeno opterećenje od POS 1: $A_{q,max} = q_{max}$ = 8.75 kN/m

povremeno opterećenje od POS 1: $C_{q,min} = q_{min}$ = -1.25 kN/m

POS 2 - maksimalni moment nad osloncem



POS 2 - maksimalni moment nad osloncem



3.3.1 Presek nad srednjim osloncem

$p_{Ed,\max} = 1.35\times 27.94 + 1.5\times 8.75 = 50.84\ kN/m = p_{Ed,1} = p_{Ed,2}$

$p_{Ed,\min} = 1.35\times 27.94 - 1.5\times 1.25 = 35.84\ kN/m = p_{Ed,3}$

$$M_{1,Ed} = -\left(\frac{p_{Ed,1}}{15} + \frac{p_{Ed,2}}{20} - \frac{p_{Ed,3}}{60}\right)\times L_1^2 = -\left(\frac{50.84}{15} + \frac{50.84}{20} - \frac{35.84}{60}\right)\times 6.0^2 = -192.0\ kNm$$

$$M_{2,Ed} = -\left(\frac{p_{Ed,3}}{15} + \frac{p_{Ed,2}}{20} - \frac{p_{Ed,1}}{60}\right)\times L_1^2 = -\left(\frac{35.84}{15} + \frac{50.84}{20} - \frac{50.84}{60}\right)\times 6.0^2 = -147.0\ kNm$$

Maksimalna reakcija oslonca B usled povremenog opterećenja:

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

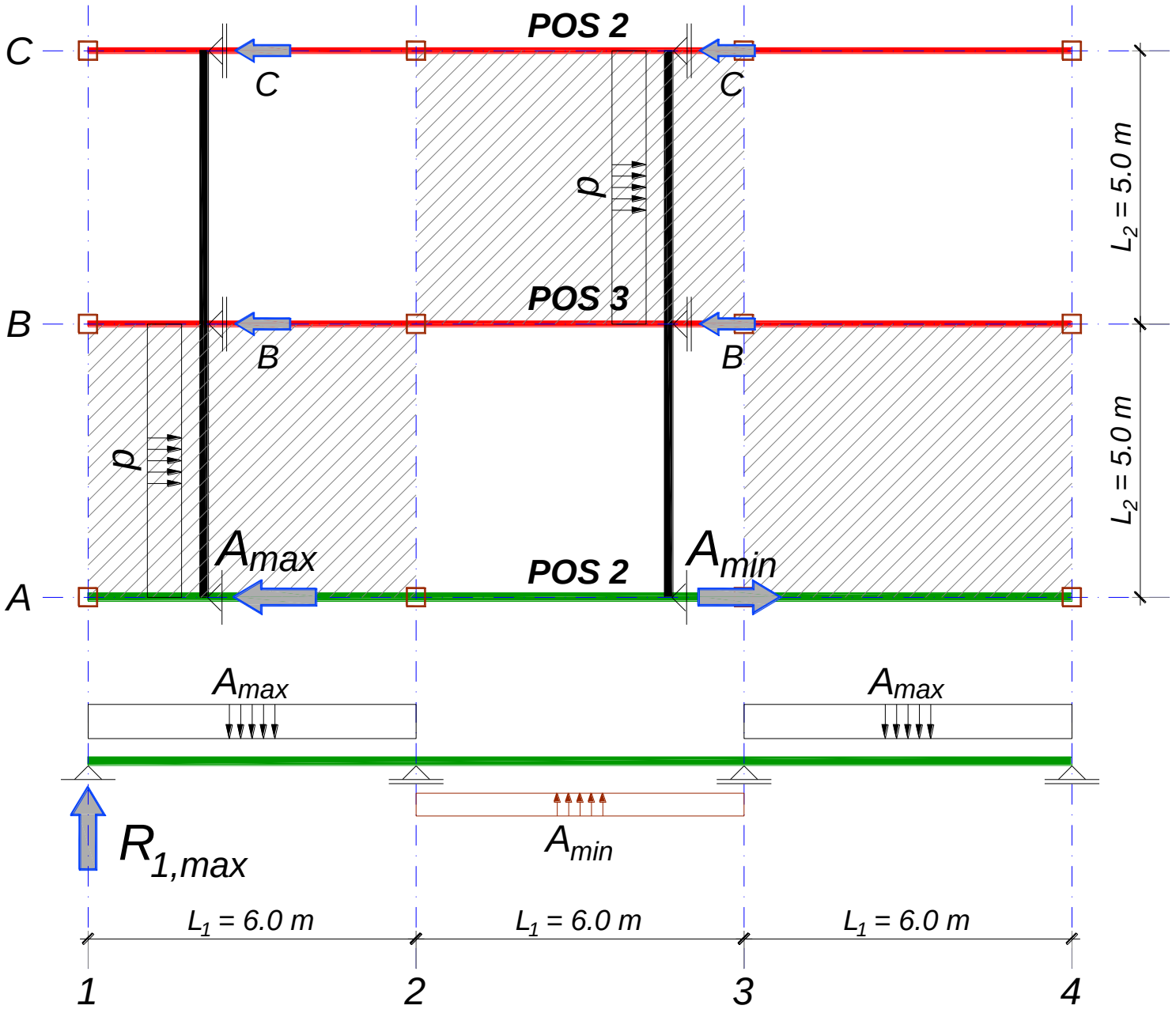
$$M_{2q} = -\left(\frac{-1.25}{15} + \frac{8.75}{20} - \frac{8.75}{60}\right)\times 6.0^2 = -7.5\ kNm$$

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

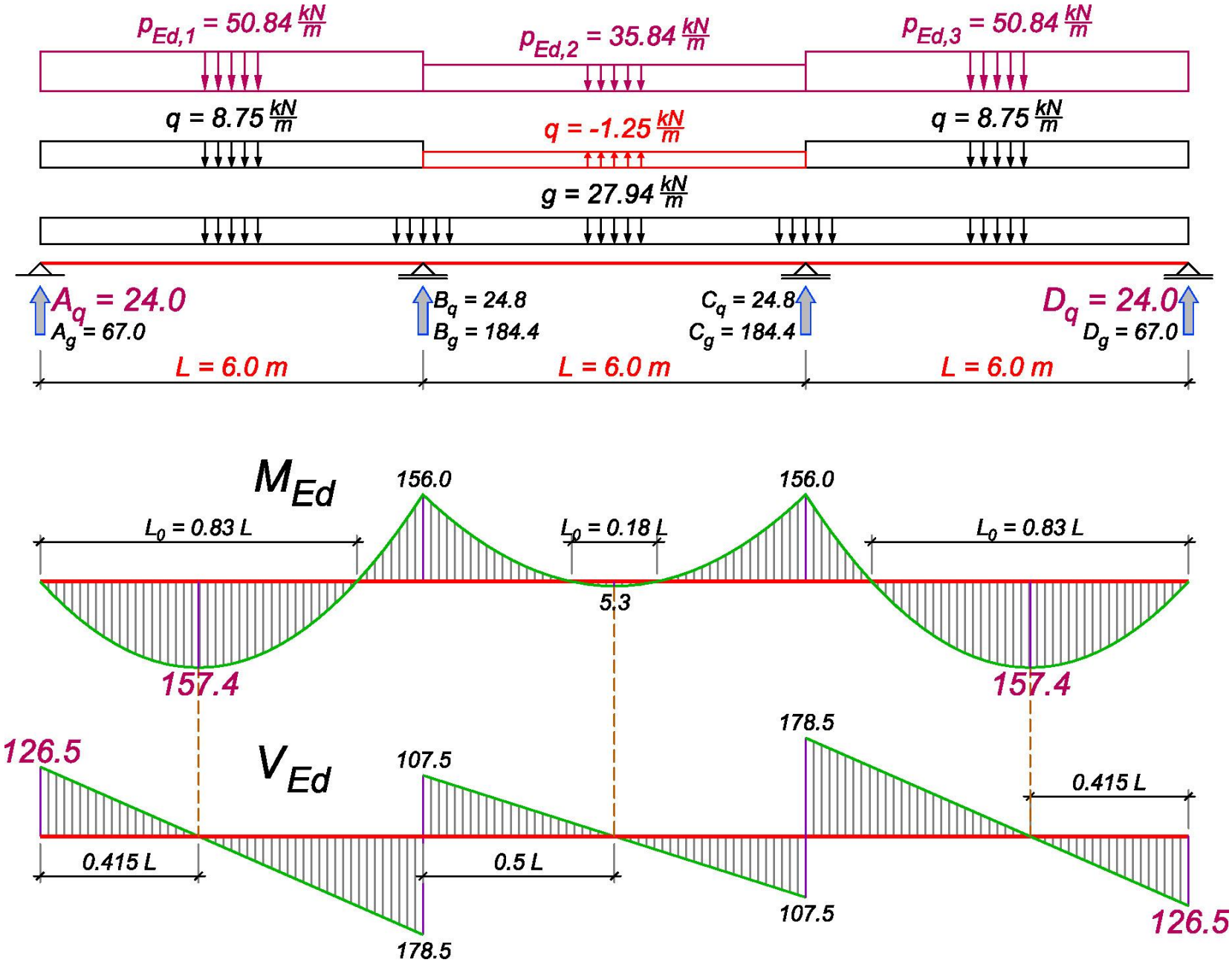
$$V_{Ed}^{A} = 1.35\times 67.0 + 1.5\times 20 = 120.5\ kN \Rightarrow V_{Ed}^{B,levo} = 120.5 - 50.84\times 6.0 = -184.5\ kN$$

$$B_{Ed} = 1.35\times 184.4 + 1.5\times 63.75 = 344.5\ kN \Rightarrow V_{Ed}^{B,desno} = 344.5 - 184.5 = 160.0\ kN$$

POS 2 - maksimalni moment u krajnjem polju



POS 2 - maksimalni moment u krajnjem polju



3.3.2 Preseci u krajnjim poljima

Kao što je pokazano u tački 2.1, potrebno je u krajnja polja naneti maksimalne, a u srednje polje mininalnu reakciju usled povremenog opterećenja sa ploče.

$$M_{1,Ed} = -\left(\frac{50.84}{15} + \frac{35.84}{20} - \frac{50.84}{60}\right) \times 6.0^2 = -156.0\,kNm = M_{2,Ed}$$

Maksimalna reakcija oslonca A usled povremenog opterećenja:

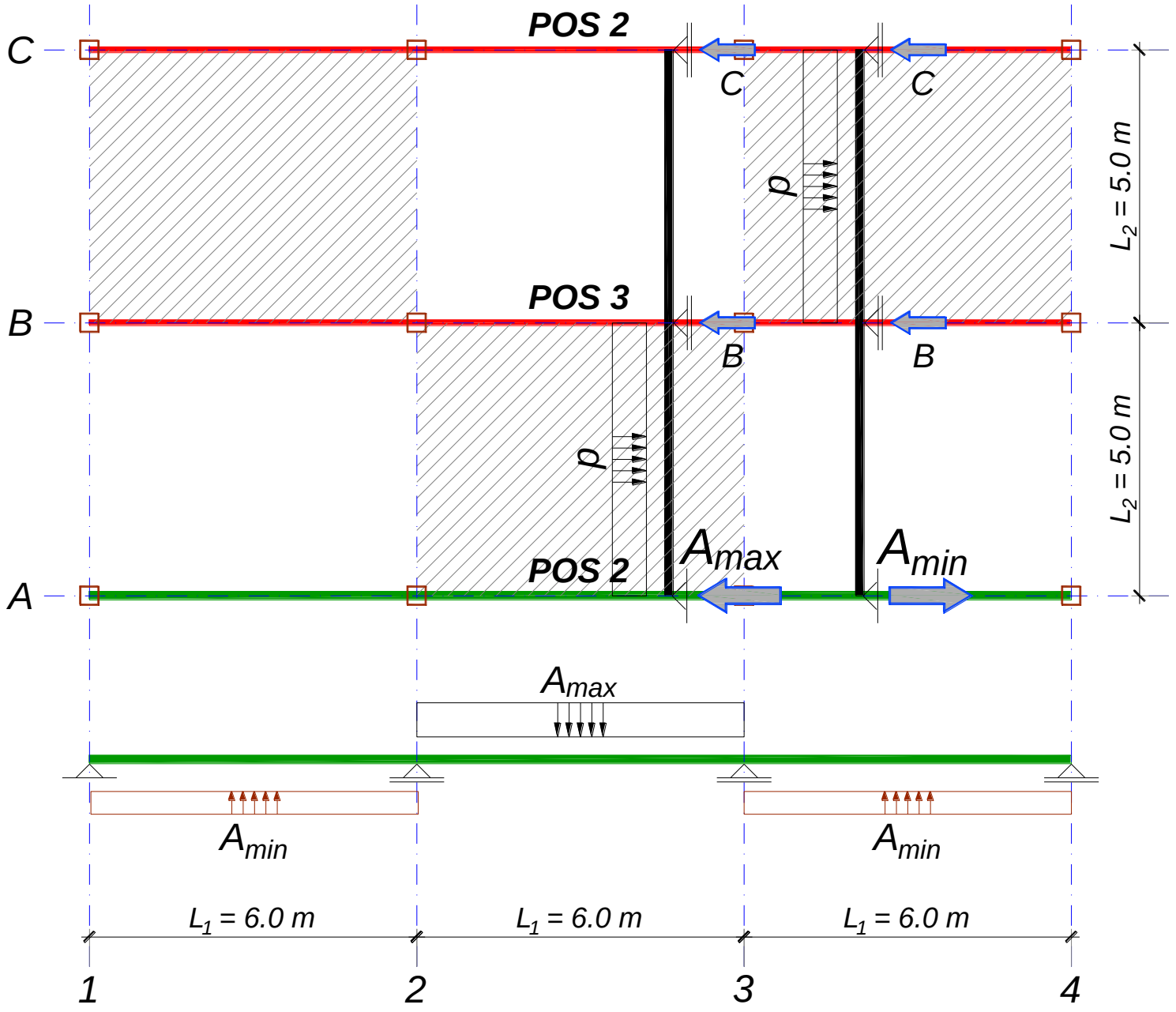
$$M_{1q} = -\left(\frac{8.75}{15} + \frac{-1.25}{20} - \frac{8.75}{60}\right) \times 6.0^2 = -13.5\,kNm = M_{1q}$$

$$A_q = \frac{8.75 \times 6.0}{2} - \frac{13.5}{6.0} = 24\,kN = A_{q,max}$$

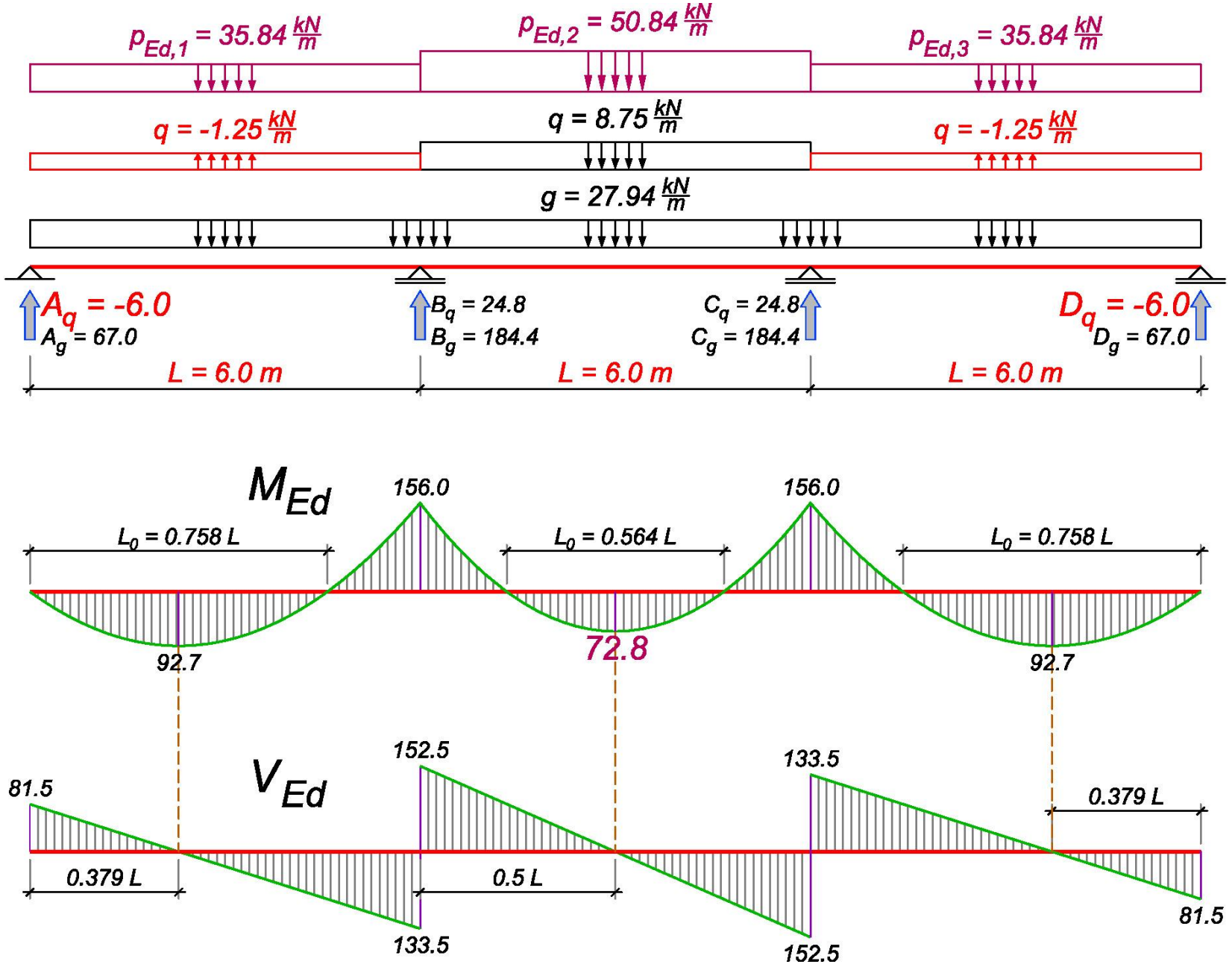
$$V_{Ed}^{A} = 1.35 \times 67.0 + 1.5 \times 24 = 126.5\,kN \Rightarrow x_{max} = \frac{126.5}{50.84} = 2.49\,m$$

$$M_{Ed,max}^{01} = 126.5 \times 2.49 - \frac{50.84 \times 2.49^2}{2} = 157.4\,kNm$$

POS 2 - maksimalni moment u srednjem polju



POS 2 - maksimalni moment u srednjem polju



3.3.3 Presek u srednjem polju

Kao što je pokazano u tački 2.1, potrebno je u krajnja polja naneti minimalne, a u srednje polje maksimalnu reakciju usled povremenog opterećenja sa ploče.

$$M_{1,Ed} = -\left(\frac{35.84}{15} + \frac{50.84}{20} - \frac{35.84}{60}\right) \times 6.0^2 = -156.0\,kNm = M_{2,Ed}$$

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

$$A_q = \frac{-1.25 \times 6.0}{2} - \frac{13.5}{6.0} = -6\,kN = A_{q,min}$$

$$M_{Ed,max}^{12} = \frac{50.84 \times 6.0^2}{8} - 156.0 = 72.8\,kNm$$

$$L_0^{12} = \sqrt{\frac{8 \times M_{Ed,max}^{12}}{p_{Ed,2}}} = \sqrt{\frac{8 \times 72.8}{50.84}} = 3.38\,m$$

Proračun sila u stubovima

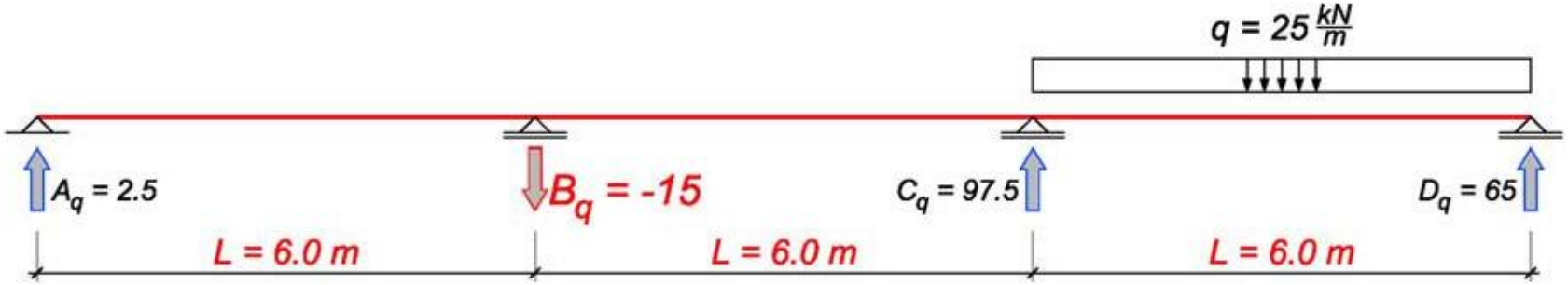
4.1 STUBOVI POS S1

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

$$G^{S1} = B_g^{POS\,3} = 280.5\,kN$$

$$Q_{max}^{S1} = B_{q,max}^{POS\,3} = 180.0\,kN \;\; (tačka\ 2.3.1)$$

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):



$$M_{1q} = \frac{25}{60} \times 6.0^2 = 15\,kNm \Rightarrow A_q = \frac{15}{6.0} = 2.5\,kN$$

$$M_{2q} = -\frac{25}{15} \times 6.0^2 = -60\,kNm \Rightarrow B_q = \frac{1}{6.0} \times \left(-60 - 2.5 \times 12.0\right) = -15\,kN$$

$$Q_{min}^{S1} = B_{q,min}^{POS\,3} = -15\,kN$$

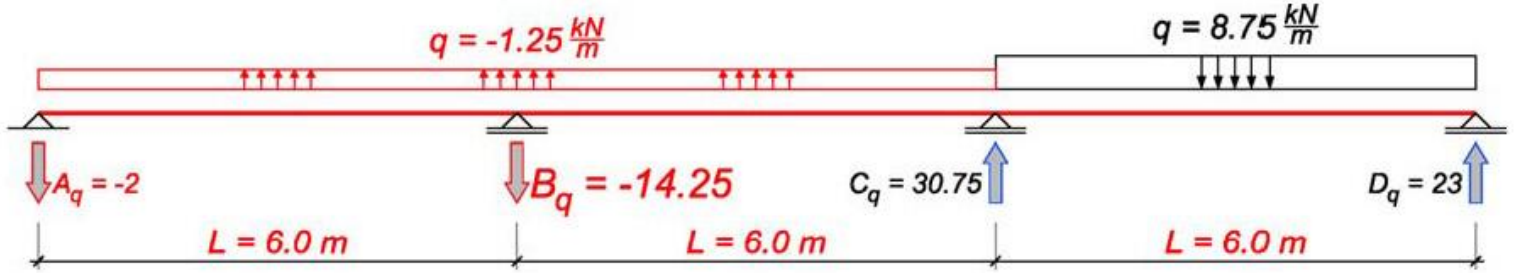
4.3 STUBOVI POS S3

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

$$G^{S3} = B_g^{POS\,2} = 206.7\,kN$$

$$Q_{max}^{S3} = B_{q,max}^{POS\,2} = 63.75\,kN \;\; (tačka\ 3.3.1)$$

Minimalna sila usled povremenog opterećenja u ovom stubu će se javiti u slučaju da se maksimalna reakcija sa ploče nađe u trećem, a minimalne u prva dva polja (odnosno, maksimalna reakcija u prvom, a minimalne u drugom i trećem polju za stub C):



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

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

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

$$Q_{min}^{S3} = B_{q,min}^{POS\,2} = -14.25\,kN$$

4.2 STUBOVI POS S2

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

$$G^{S2} = A_g^{POS3} + B_g^{POS4} = 102.0 + 104.5 = 206.3\,kN$$

$$Q_{max}^{S2} = A_{q,max}^{POS3} = 67.5\,kN \text{ (tačka 2.3.2)}$$

$$Q_{min}^{S2} = A_{q,min}^{POS3} = -7.5\,kN \text{ (tačka 2.3.3)}$$

4.4 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 POS 4:

$$G^{S4} = A_g^{POS2} + A_g^{POS4} = 67.0 + 31.3 = 98.3\,kN$$

$$Q_{max}^{S4} = A_{q,max}^{POS2} = 24\,kN \text{ (tačka 3.3.2)}$$

$$Q_{min}^{S4} = A_{q,min}^{POS2} = -6\,kN \text{ (tačka 3.3.3)}$$

Poređenje uticaja (totalno q / ekstremne vrednosti)

		totalno	ekstremi	Δ
POS 1	M_{Ed}^{osl}	44,1	44,1	0,00%
	M_{Ed}^{polje}	24,8	28,4	14,69%
	$V_{Ed,max}$	44,1	44,1	0,00%
POS 2	M_{Ed}^{0-1}	141,0	157,4	11,63%
	M_{Ed}^{1}	176,3	192,0	8,94%
	M_{Ed}^{1-2}	44,1	72,8	65,10%
	V_{Ed}^{A}	117,5	126,5	7,66%
	$V_{Ed}^{B,levo}$	176,3	184,5	4,68%
	$V_{Ed}^{B,desno}$	146,9	160,0	8,94%
POS 3	M_{Ed}^{0-1}	273,2	300,9	10,13%
	M_{Ed}^{1}	341,6	364,1	6,59%
	M_{Ed}^{1-2}	85,4	152,9	79,05%
	V_{Ed}^{A}	227,7	239,0	4,94%
	$V_{Ed}^{B,levo}$	341,6	345,3	1,10%
	$V_{Ed}^{B,desno}$	284,6	303,4	6,59%

Poređenje uticaja (totalno q / ekstremne vrednosti)

		totalno	ekstremi	Δ
S1	G	280,5	280,5	
	Q_{max}	165,0	180,0	9,09%
	Q_{min}		-15,0	–
S2	G	206,3	206,3	
	Q_{max}	60,0	67,5	6,25%
	Q_{min}		-7,5	–
S3	G	184,4	184,4	
	Q_{max}	49,5	63,75	36,36%
	Q_{min}		-14,25	–
S4	G	98,3	98,3	
	Q_{max}	18,0	24,0	33,33%
	Q_{min}		-6	–

POS 3, POS 2 – poređenje uticaja