

Assignment 7

Larina Ponomarenko

$$a = 5,4 \text{ m}$$

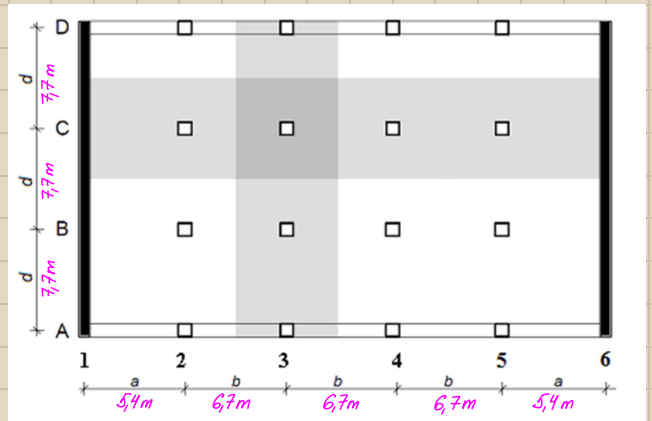
$$b = 6,7 \text{ m}$$

$$d = 7,7 \text{ m}$$

C25/30

$$(g - g_0)_{\text{floor},k} = 1,4 \text{ kN/m}^2$$

$$q_{\text{floor},k} = 4,9 \text{ kN/m}^2$$



1. Design of dimensions

1.1 Slab thickness

$$h_{d,1} = \frac{L_{n,\max}}{30} = \frac{7700 - 2 \cdot 200}{30} = 243 \text{ mm (assume column } 400 \times 400)$$

$$h_{d,2} = c + \frac{\phi_s}{2} + \frac{L_{\max}}{K_{c1} \cdot K_{c2} \cdot K_{c3} \cdot l_{d,\text{tab}}}$$

For concrete C25/30 $l_{d,\text{tab}} = 22,2$

Preliminarily take $\phi 12 \text{ mm} \Rightarrow c = 25 \text{ mm (from task 1)}$

$$h_{d,2} = 25 + 6 + \frac{7700}{1,2 \cdot 22,2} = 320 \text{ mm}$$

$\Rightarrow$ choose $h_s = 300 \text{ mm}$

Span - depth ratio:

* must be d instead of h_s

$$\lambda = \frac{L_s}{h_s} = \frac{7700}{300} = 25,67$$

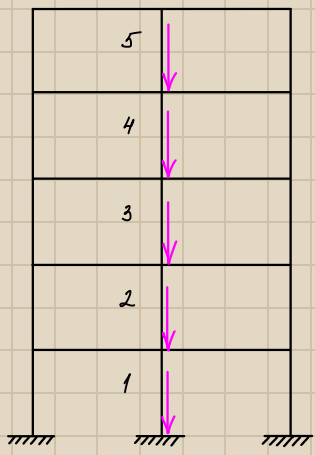
h_s , we agreed that /

$$\lambda_d = 1,2 \cdot 22,2 = 26,64$$

don't have to change it $\lambda \neq \lambda_d \checkmark$

1.2 Wall thickness

$$a = 5,4 \text{ m} < 6 \text{ m} \Rightarrow b_w = 200 \text{ mm}$$



1.3 Perimeter beam dimensions

$$h_b = 950 \text{ mm}$$

$$b_b = 200 \text{ mm}$$

1.4 Column dimensions

Loading of the slab

Load type	k-value [kN/m ²]	γ	design value [kN/m ²]
	$25 \text{ kN/m}^3 \cdot 0,3 \text{ m} =$		
Self-weight	7,5	1,35	10,125
Dead load	1,4	1,35	1,89
Live load	4,9	1,5	7,35
Total	13,8		19,4

Tributing area of column:

$$6,7 \cdot 7,7 = 51,6 \text{ m}^2$$

Teacher's note:
This is incorrect! This is the specific weight of concrete, and it is 25 (and not 0.25)

Self-weight of the column (preliminarily take $400 \times 400 \text{ mm}$)

$$0,25 \cdot 0,4^2 \cdot (3,5 - 0,3) = 0,128 \text{ kN}$$

1st floor:

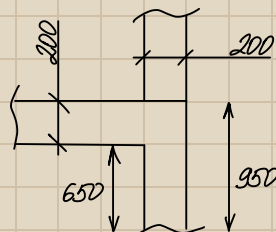
$$N_{ed} = (19,4 \cdot 51,6 + 0,128) \cdot 5 = 5006,2 \text{ kN}$$

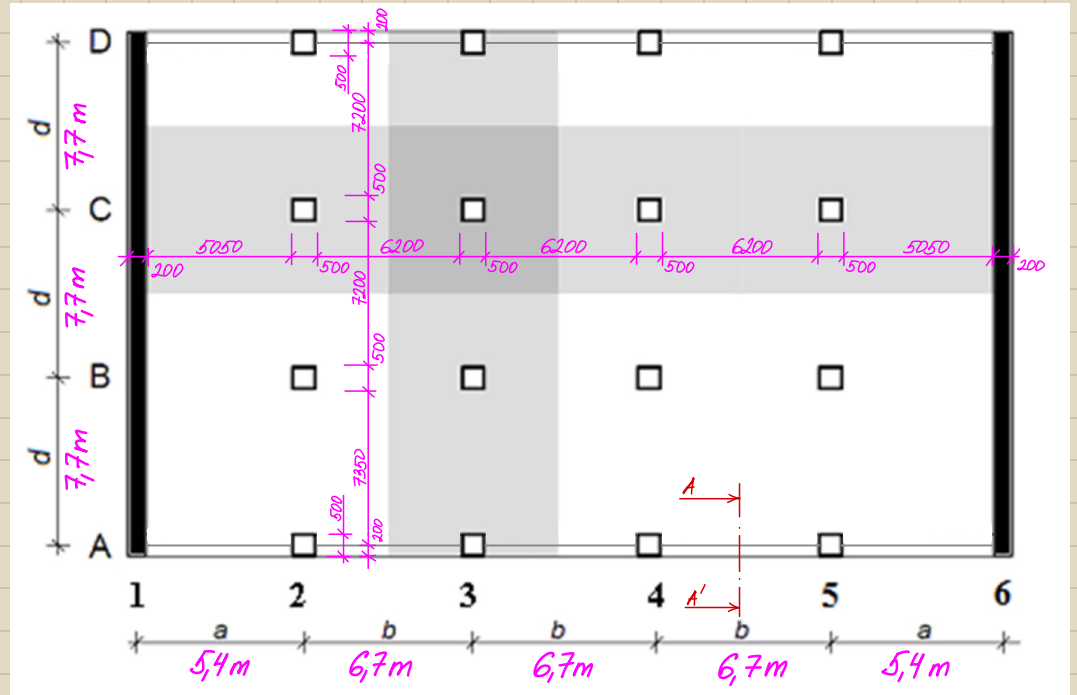
$$A_{c,reqd} = \frac{N_{ed}}{0,8 f_{cd} + 0,02 \cdot 400 \text{ MPa}} = \frac{5006,2}{0,8 \cdot 16,67 + 0,02 \cdot 400} = 0,2346 \text{ m}^2$$

$$A_c = 0,4^2 = 0,16 \text{ m}^2 - \text{doesn't suffice}$$

$$\text{Take } A_c = 0,5^2 = 0,25 \text{ m}^2 \checkmark$$

Section A-A'





2. Preliminary check of slab punching

$U_0 = 4a = 4 \cdot 0,5 = 2 \text{ m}$ - face of the column

$$d = 300 - 25 - 6 = 269 \text{ mm}$$

$$u_1 = 4a + 2\pi \cdot 2d = 2 + 4 \cdot 0,269\pi = 5,38 \text{ m} - 2d \text{ from } u_0$$

Failure of compressed concrete at σ_0 :

$$V_{ed,0} = \frac{\beta V_{ed}}{u_0 \cdot d} \leq V_{ed,max} = 0,4 V \cdot f_{cd}$$

$$v = 0,6 \left(1 - \frac{f_k}{250} \right) = 0,6 \left(1 - \frac{25}{250} \right) = 0,54$$

$$\Rightarrow V_{d, \max} = 94 \cdot 0,54 \cdot 16,67 \cdot 10^3 = 3600,7 \text{ kPa}$$

$$\beta = 1,15$$

$$V_{ed} (1 \text{ floor}) = 19,4 \cdot 51,6 + 0,2 = 1001,24 \text{ kN}$$

$$\Rightarrow v_{Ed0} = \frac{1,15 \cdot 1001,24}{2 \cdot 0,269} = 2140,2 \text{ kPa}$$

$$2140,2 < 3600,7 \quad \checkmark$$

Condition is satisfied, so no caps

Failure of punching reinforcement at u_1 :

Checking if it could be anchored:

$$V_{Ed,1} = \frac{B V_{Ed}}{u_1 \cdot d} \leq k_{max} \cdot V_{Rd,c} = k_{max} \cdot C_{Rd,c} \cdot k \cdot \sqrt[3]{100 \rho_1 \cdot f_{ct}}$$

$$V_{Ed,1} = \frac{1,15 \cdot 1001,24}{5,38 \cdot 0,269} = 795,6 \text{ kPa}$$

Coefficient of max. resistance $k_{max} = 1,8$ (for double-headed studs)

Reduction factor $C_{Rd,c} = 0,12$

Effect of depth:

$$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{269}} = 1,86 \leq 2$$

$$\rho_1 = 0,005$$

$$\Rightarrow k_{max} \cdot V_{Rd,c} = 1,8 \cdot 0,12 \cdot 1,86 \sqrt[3]{100 \cdot 0,005 \cdot 25} = 932,4 \text{ MPa}$$

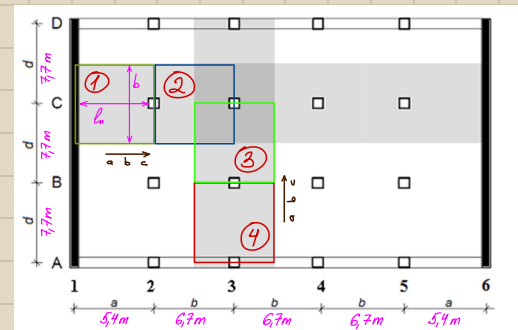
$$795,6 \text{ kPa} < 932,4 \text{ kPa} \checkmark$$

3. Bending moments

Total bending moment in a panel:

$$f_d = 19,4 \text{ kN/m}^2$$

$$M_{tot} = \frac{1}{8} f_d \cdot b \cdot l_n^2$$



$$\text{Panel 1) } M_{tot}^1 = \frac{1}{8} \cdot 19,4 \cdot 7,7 (5,4 - 0,25 - 0,1)^2 = 476,2 \text{ kNm}$$

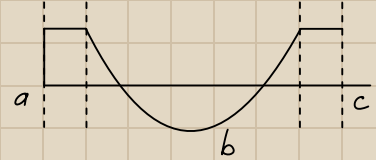
$$\text{Panel 2) } M_{tot}^2 = \frac{1}{8} \cdot 19,4 \cdot 7,7 (6,7 - 0,25 \cdot 2)^2 = 717,8 \text{ kNm}$$

$$\text{Panel 3) } M_{tot}^3 = \frac{1}{8} \cdot 19,4 \cdot 6,7 (7,7 - 0,25 \cdot 2)^2 = 842,3 \text{ kNm}$$

$$\text{Panel 4) } M_{tot}^4 = \frac{1}{8} \cdot 19,4 \cdot 6,7 (7,7 - 0,25 \cdot 2)^2 = 842,3 \text{ kNm}$$

Support and mid-span moments:

$$M = f_i \cdot M_{tot}^i$$



Panel 1) $f_a = 0,65$

$$f_b = 0,35$$

$$f_c = 0,65$$

$$M_a^1 = 0,65 \cdot 476,2 = 309,5 \text{ kNm}$$

$$M_b^1 = 0,35 \cdot 476,2 = 166,7 \text{ kNm}$$

$$M_c^1 = 0,65 \cdot 476,2 = 309,5 \text{ kNm}$$

Panel 2) $f_a = 0,65$

$$f_b = 0,35$$

$$f_c = 0,65$$

$$M_a^2 = 0,65 \cdot 717,8 = 466,6 \text{ kNm}$$

$$M_b^2 = 0,35 \cdot 717,8 = 251,2 \text{ kNm}$$

$$M_c^2 = 0,65 \cdot 717,8 = 466,6 \text{ kNm}$$

Panel 3) $f_a = 0,65$

$$f_b = 0,35$$

$$f_c = 0,65$$

$$M_a^3 = 0,65 \cdot 842,3 = 547,5 \text{ kNm}$$

$$M_b^3 = 0,35 \cdot 842,3 = 294,8 \text{ kNm}$$

$$M_c^3 = 0,65 \cdot 842,3 = 547,5 \text{ kNm}$$

Panel 4) $f_a = 0,3$

$$f_b = 0,5$$

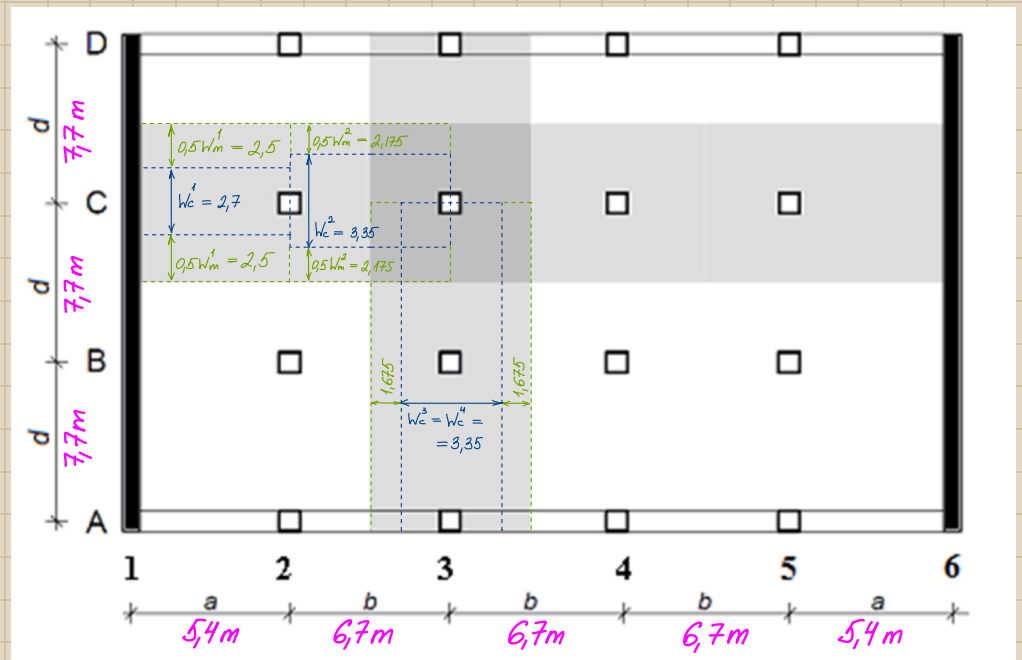
$$f_c = 0,7$$

$$M_a^4 = 0,3 \cdot 842,3 = 252,7 \text{ kNm}$$

$$M_b^4 = 0,5 \cdot 842,3 = 421,2 \text{ kNm}$$

$$M_c^4 = 0,7 \cdot 842,3 = 589,6 \text{ kNm}$$

Moments in column and middle strips



Panel 1)

$$w_c^1 = 2 \cdot 0,25 \cdot 5,4 = 2,7 \text{ m}$$

$$w_m^1 = 7,7 - 2,7 = 5 \text{ m} \Rightarrow 0,5 w_m^1 = 2,5 \text{ m}$$

Panel 2)

$$w_c^2 = 2 \cdot 0,25 \cdot 6,7 = 3,35 \text{ m}$$

$$w_m^2 = 7,7 - 3,35 = 4,35 \text{ m} \Rightarrow 0,5 w_m^2 = 2,175 \text{ m}$$

Panel 3)

$$w_c^3 = 2 \cdot 0,25 \cdot 6,7 = 3,35 \text{ m}$$

$$w_m^3 = 6,7 - 3,35 = 3,35 \text{ m} \Rightarrow 0,5 w_m^3 = 1,675 \text{ m}$$

Panel 4)

same as for panel 4

We must split the moments into column and middle strip moments

$$M_c = w (j_i \cdot M_{tot})$$

$$M_m = (1 - w) (j_i \cdot M_{tot})$$

mid-span: $w = 0,6$

inner support: $w = 0,75$

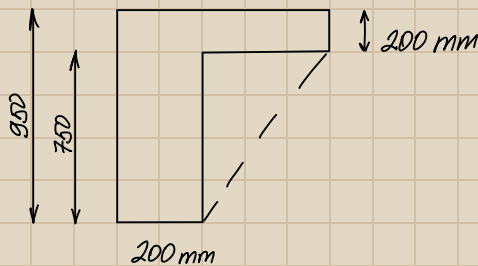
edge beam: $w = \min(\max(1 - \frac{\beta_t}{10}, 0,75); 1)$

$$\beta_t = \frac{l_t}{2l_s}$$

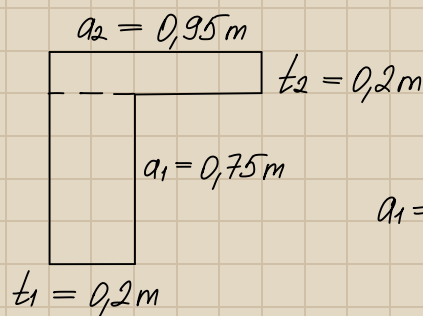
$$l_s = \frac{1}{12} b h_s^3 = \frac{1}{12} \cdot 6,7 \cdot 0,3^3 = 0,015 \text{ m}^4$$

$$l_t = \sum_{i=1}^n \left(1 - 0,63 \cdot \frac{t_i}{a_i}\right) \cdot \frac{t_i^3 \cdot a_i}{3}$$

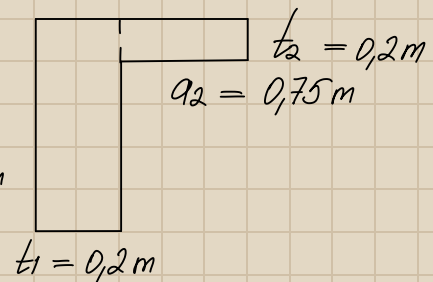
$$\overleftarrow{750} \quad h_v \leq 4h_s \Rightarrow h_v \leq 800 \text{ mm}$$



a)



b)



$$l_t^a = \left(1 - 0,63 \cdot \frac{0,2}{0,75}\right) \cdot \frac{0,2^3 \cdot 0,75}{3} + \left(1 - 0,63 \cdot \frac{0,2}{0,95}\right) \cdot \frac{0,2^3 \cdot 0,95}{3} = 0,00386 \text{ m}^4$$

$$l_t^b = \left(1 - 0,63 \cdot \frac{0,2}{0,95}\right) \cdot \frac{0,2^3 \cdot 0,95}{3} + \left(1 - 0,63 \cdot \frac{0,2}{0,75}\right) \cdot \frac{0,2^3 \cdot 0,75}{3} = 0,00386 \text{ m}^4$$

$$\beta_t = \frac{0,00386}{2 \cdot 0,015} = 0,12$$

$$\omega = \min(\max(1 - \frac{0,12}{10}, 0,75); 1) = \min(\max(0,988; 0,75); 1) = 0,988$$

$$M_c = \omega (j_i \cdot M_{tot})$$

$$M_m = (1 - \omega)(j_i \cdot M_{tot})$$

mid-span: $\omega = 0,6$

inner support: $\omega = 0,75$

edge beam: $\omega = 0,988$

Panel 1)

(wall) $m_w^1 = \frac{309,5}{7,7} = 40,2 \text{ kNm/m}$

$$M_a^1 = 0,65 \cdot 476,2 = 309,5 \text{ kNm}$$

$$M_b^1 = 0,35 \cdot 476,2 = 166,7 \text{ kNm}$$

$$M_c^1 = 0,65 \cdot 476,2 = 309,5 \text{ kNm}$$

$$W_c^1 = 2 \cdot 0,25 \cdot 5,4 = 2,7 \text{ m}$$

$$W_m = 7,7 - 2,7 = 5 \text{ m}$$

$$m_m^{1b} = \frac{(1 - 0,6) \cdot 166,7}{5} = 13,4 \text{ kNm/m}$$

$$m_c^{1b} = \frac{0,6 \cdot 166,7}{2,7} = 37,0 \text{ kNm/m}$$

$$m_m^{1c} = \frac{(1 - 0,75) \cdot 309,5}{5} = 15,5 \text{ kNm/m}$$

$$m_c^{1c} = \frac{0,75 \cdot 309,5}{2,7} = 86,0 \text{ kNm/m}$$

Panel 2)

$$M_a^2 = 0,65 \cdot 717,8 = 466,6 \text{ kNm}$$

$$M_b^2 = 0,35 \cdot 717,8 = 251,2 \text{ kNm}$$

$$M_c^2 = 0,65 \cdot 717,8 = 466,6 \text{ kNm}$$

$$W_c^2 = 2 \cdot 0,25 \cdot 6,7 = 3,35 \text{ m}$$

$$W_m = 7,7 - 3,35 = 4,35 \text{ m}$$

$$m_m^{2a} = \frac{(1 - 0,75) \cdot 466,6}{4,35} = 26,8 \text{ kNm/m}$$

$$m_c^{2a} = \frac{0,75 \cdot 466,6}{3,35} = 104,5 \text{ kNm/m}$$

$$m_m^{2b} = \frac{(1-0,6) \cdot 251,2}{4,35} = 23,1 \text{ kNm/m}$$

$$m_c^{2b} = \frac{0,6 \cdot 251,2}{3,35} = 45,0 \text{ kNm/m}$$

$$m_m^{2c} = \frac{(1-0,75) \cdot 466,6}{4,35} = 26,8 \text{ kNm/m}$$

$$m_c^{2c} = \frac{0,75 \cdot 466,6}{3,35} = 104,5 \text{ kNm/m}$$

Panel 3)

$$M_a^3 = 0,65 \cdot 842,3 = 547,5 \text{ kNm}$$

$$M_b^3 = 0,35 \cdot 842,3 = 294,8 \text{ kNm}$$

$$M_c^3 = 0,65 \cdot 842,3 = 547,5 \text{ kNm}$$

$$w_c^3 = 2 \cdot 0,25 \cdot 6,7 = 3,35 \text{ m}$$

$$w_m = 6,7 - 3,35 = 3,35 \text{ m}$$

$$m_m^{3a} = \frac{(1-0,75) \cdot 547,5}{3,35} = 40,9 \text{ kNm/m}$$

$$m_c^{3a} = \frac{0,75 \cdot 547,5}{3,35} = 122,6 \text{ kNm/m}$$

$$m_m^{3b} = \frac{(1-0,6) \cdot 294,8}{3,35} = 35,2 \text{ kNm/m}$$

$$m_c^{3b} = \frac{0,6 \cdot 294,8}{3,35} = 52,8 \text{ kNm/m}$$

$$m_m^{3c} = \frac{(1-0,75) \cdot 547,5}{3,35} = 40,9 \text{ kNm/m}$$

$$m_c^{3c} = \frac{0,75 \cdot 547,5}{3,35} = 122,6 \text{ kNm/m}$$

Panel 4)

$$M_a^4 = 0,3 \cdot 842,3 = 252,7 \text{ kNm}$$

$$M_b^4 = 0,5 \cdot 842,3 = 421,2 \text{ kNm}$$

$$M_c^4 = 0,7 \cdot 842,3 = 589,6 \text{ kNm}$$

$$m_m^{4a} = \frac{(1-0,988) \cdot 252,7}{3,35} = 0,9 \text{ kNm/m}$$

$$m_c^{4a} = \frac{0,988 \cdot 252,7}{3,35} = 74,5 \text{ kNm/m}$$

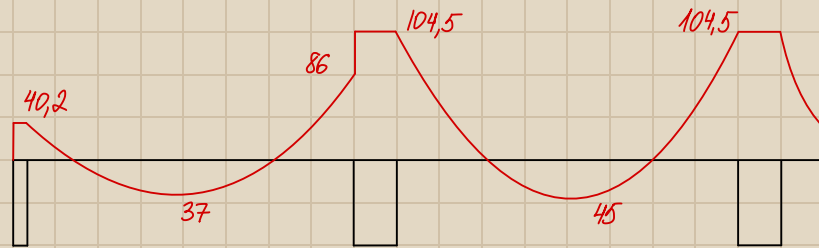
$$m_m^{4b} = \frac{(1-0,6) \cdot 421,2}{3,35} = 50,3 \text{ kNm/m}$$

$$m_c^{4b} = \frac{0,6 \cdot 421,2}{3,35} = 75,4 \text{ kNm/m}$$

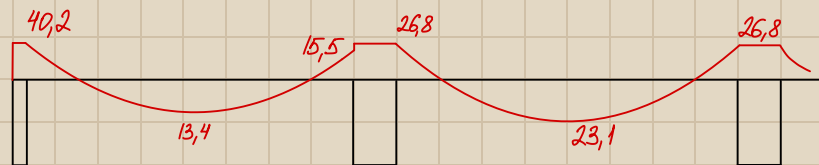
$$M_m^{\text{3c}} = \frac{(1 - 0,75) \cdot 589,6}{3,35} = 44,0 \text{ kNm/m}$$

$$M_c^{\text{3c}} = \frac{0,75 \cdot 589,6}{3,35} = 132,0 \text{ kNm/m}$$

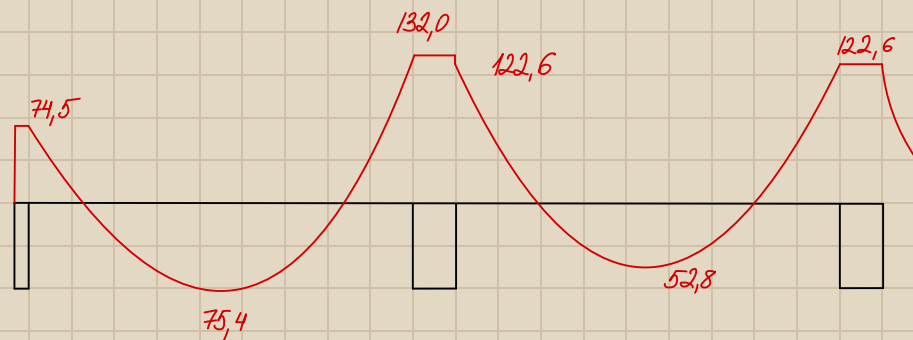
Belt C -
column strip



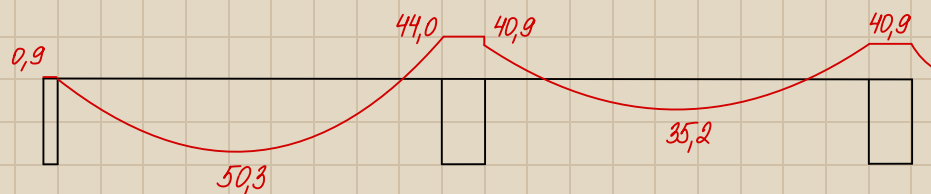
Belt C -
middle strip



Belt 3 -
column strip



Belt 3 -
middle strip



Moments in middle and column strip							
Panel	Cross-section	Positive/negative moment M_i [kNm]	Strip	w	Moment in middle/ column strip M_j [kNm]	Width of the strip s_j [m]	Moment per 1m of the slab m_j [kNm/m]
1	a (left support)	309,5	no division	1	309,5	7,7	40,2
	b (midspan)	166,7	middle	0,6	66,7	5	13,3
			column		100,0	2,7	37,0
	c (right support)	309,5	middle	0,75	77,4	5	15,5
			column		232,1	2,7	86,0
2	a (left support)	466,6	middle	0,75	116,7	4,35	26,8
			column		350,0	3,35	104,5
	b (midspan)	251,2	middle	0,6	100,5	4,35	23,1
			column		150,7	3,35	45,0
	c (right support)	466,6	middle	0,75	116,7	4,35	26,8
			column		350,0	3,35	104,5
3	a (left support)	547,5	middle	0,75	136,9	3,35	40,9
			column		410,6	3,35	122,6
	b (midspan)	294,8	middle	0,6	117,9	3,35	35,2
			column		176,9	3,35	52,8
	c (right support)	547,5	middle	0,75	136,9	3,35	40,9
			column		410,6	3,35	122,6
4	a (left support)	252,7	middle	0,988	3,0	3,35	0,9
			column		249,7	3,35	74,5
	b (midspan)	421,2	middle	0,6	168,5	3,35	50,3
			column		252,7	3,35	75,4
	c (right support)	589,6	middle	0,75	147,4	3,35	44,0
			column		442,2	3,35	132,0