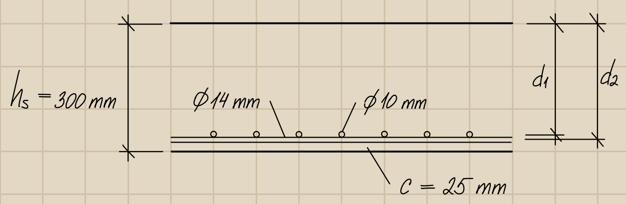
Assignment 8 Darina Ponomarenko

Design of bending reinforcement

1. Effective depth of slab

The extreme $m_{Ed} = 137{,}6$ kNm/m occurs in the belt 3



$d_1 = 300 - 25 - 14 - 5 = 256$ mm – for belt C

$d_2 = 300 - 25 - 7 = 268$ mm – for belt 3

2. Required area of reinforcement

$$a_{s,rqd} = \frac{m_{Ed}}{z \cdot f_{yd}} \; ; \quad z \approx 0{,}9d$$

I will proceed with $m_{Ed} = 137{,}6$ kNm/m for manual calculation

$$a_{s,rqd}^{4c-c} = \frac{137{,}6 \cdot 10^6}{0{,}9 \cdot 0{,}268 \cdot 434{,}78 \cdot 10^3} = 1312 \text{ mm}^2$$

3. Minimum reinforcement area

1) $a_{s,min,1} = 0{,}0013\,bd = 0{,}0013 \cdot 1000 \cdot 268 = 348 \text{ mm}^2$

2) $a_{s,min,2} = \frac{0{,}26 \cdot f_{ctm}}{f_{yk}} \cdot bd = \frac{0{,}26 \cdot 2{,}6 \cdot 10^3}{500 \cdot 10^3} \cdot 1 \cdot 0{,}268 \cdot 10^6 = 362 \text{ mm}^2$

bd?

3) $a_{s,min,3} = \frac{k_c \cdot k \cdot f_{ct,eff} \cdot a_{ct}}{\sigma_s} = \frac{0{,}4 \cdot 1 \cdot f_{ctm}(1 \cdot 0{,}5\,hd)}{f_{yk}} =$

$$= \frac{0{,}4 \cdot 2{,}6 \cdot 10^3 \cdot 0{,}5 \cdot 1 \cdot 0{,}268 \cdot 10^6}{500 \cdot 10^3} = 279 \text{ mm}^2$$

$a_{s,min} = 362 \text{ mm}^2$ for belt 3

4. Reinforcement design

Design $\phi 14$ per 100 mm

$$a_{s,prov}^{4c-c} = n_s \cdot a_{s,1} = \frac{1000}{S} \cdot \frac{\pi \phi_s^2}{4} = \frac{1000}{100} \cdot \frac{\pi \cdot 14^2}{4} = 1539 \text{ mm}^2$$

(17% > $a_{s,rqd}$)

5. Assessment of the design

1) height of compressed zone

$$x = \frac{a_{s,prov} \cdot f_{yd}}{0{,}8 b \cdot f_{cd}} = \frac{1539 \cdot 10^{-6} \cdot 434{,}78}{0{,}8 \cdot 1 \cdot 16{,}67} = 0{,}050 \text{ m} = 50 \text{ mm}$$

2) lever arm

$$z = d - 0{,}4x = 268 - 0{,}4 \cdot 50 = 248 \text{ mm}$$

3) load-bearing capacity of the CS

$$M_{Rd} = a_{s,prov} \cdot f_{yd} \cdot z = 1539 \cdot 10^{-6} \cdot 434{,}78 \cdot 10^{3} \cdot 0{,}248 = 165{,}9 \text{ kNm/m}$$

$165{,}9 > 137{,}6$ ✓

6. Detailing rules

1) relative height of compressed zone

$$\xi = \frac{x}{d} \leq 0{,}45$$

$$\frac{50}{268} = 0{,}19 < 0{,}45 \checkmark$$

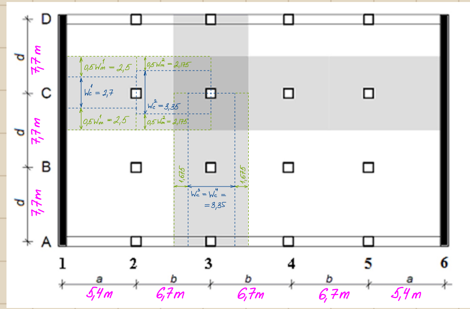
2) spacing of rebars

$$s \leq \min(2h_s; 250 \text{ mm}) = \min(600 \text{ mm}; 250 \text{ mm}) = 250 \text{ mm}$$

$100 < 250$ ✓

Moments in middle and column strip																			
			Design										Check						
Panel	Cross-section	Strip	m_{Ed} [kNm/m]	d [mm]	z [mm]	$a_{s,rqd}$ [mm^2]	$a_{s,min}$ [mm^2]	⌀ [mm]	sp [mm]	$a_{s,prov}$ [mm^2]	%	x [mm]	ξ	z [mm]	m_{Rd} [kNm/m]	$m_{Rd} > m_{Ed}$	$\xi < 0{,}45$	sp
1	a (left support)	no division	40,2	256	230	401	346	14	250	616	53	20	0,08	248	66	OK	OK	OK
	b (midspan)	middle	13,3	256	230	133	346	10	200	393	196	13	0,05	251	43	OK	OK	OK
		column	37,0	256	230	369	346	14	250	616	67	20	0,08	248	66	OK	OK	OK
	c (right support)	middle	15,5	256	230	155	346	10	200	393	154	13	0,05	251	43	OK	OK	OK
		column	86,0	256	230	859	346	14	120	1283	49	42	0,16	239	133	OK	OK	OK
2	a (left support)	middle	26,8	256	230	268	346	10	200	393	47	13	0,05	251	43	OK	OK	OK
		column	104,5	256	230	1043	346	14	120	1283	23	42	0,16	239	133	OK	OK	OK
	b (midspan)	middle	23,1	256	230	231	346	10	200	393	70	13	0,05	251	43	OK	OK	OK
		column	45,0	256	230	449	346	14	250	616	37	20	0,08	248	66	OK	OK	OK
	c (right support)	middle	26,8	256	230	268	346	10	200	393	47	13	0,05	251	43	OK	OK	OK
		column	104,5	256	230	1043	346	14	120	1283	23	42	0,16	239	133	OK	OK	OK
3	a (left support)	middle	40,9	268	241	390	362	10	150	524	34	17	0,06	261	59	OK	OK	OK
		column	122,6	268	241	1169	362	14	100	1539	32	50	0,19	248	166	OK	OK	OK
	b (midspan)	middle	35,2	268	241	336	362	10	200	393	17	13	0,05	263	45	OK	OK	OK
		column	52,8	268	241	503	362	14	250	616	22	20	0,07	260	70	OK	OK	OK
	c (right support)	middle	40,9	268	241	390	362	10	150	524	34	17	0,06	261	59	OK	OK	OK
		column	122,6	268	241	1169	362	14	100	1539	32	50	0,19	248	166	OK	OK	OK
4	a (left support)	middle	0,9	268	241	9	362	10	200	393	4476	13	0,05	263	45	OK	OK	OK
		column	74,5	268	241	710	362	14	150	1026	44	33	0,12	255	114	OK	OK	OK
	b (midspan)	middle	50,3	268	241	480	362	10	120	654	36	21	0,08	259	74	OK	OK	OK
		column	75,4	268	241	719	362	14	150	1026	43	33	0,12	255	114	OK	OK	OK
	c (right support)	middle	44,0	268	241	420	362	10	150	524	25	17	0,06	261	59	OK	OK	OK
		column	132,0	268	241	1259	362	14	100	1539	22	50	0,19	248	166	OK	OK	OK

7. Anchorage



Panel 1)

column strip: $\frac{l_n}{3} = \frac{5050}{3} \Rightarrow 1690\ mm$

middle strip: $\frac{l_n}{4} \Rightarrow 1270\ mm$

Panel 2)

column: $\frac{6200}{3} \Rightarrow 2070\ mm$

middle: $\frac{6200}{4} \Rightarrow 1550\ mm$

Panel 3,4)

column: $\frac{7200}{3} \Rightarrow 2400\ mm$

middle: $\frac{7200}{4} \Rightarrow 1800\ mm$

Edge reinforcement

Basic anchorage length: $l_{b,req} = \frac{\phi}{4} \cdot \frac{\sigma_{sd}}{f_{bd}}$

$\sigma_{sd} = f_{yd}$

$f_{bd} = 2,25 \eta_1 \cdot \eta_2 \cdot f_{ctd}$

$\eta_1 = \eta_2 = 1$

$f_{ctd} = \frac{f_{ctk,0.05}}{1,5} = \frac{1,8}{1,5} = 1,2\ MPa$

$f_{bd} = 2,25 \cdot 1,2 = 2,7\ MPa$

For $\phi 10$: $l_{b,req} = \frac{10}{4} \cdot \frac{434,78}{2,7} = 403\ mm$

For $\phi 14$: $l_{b,req} = \frac{14}{4} \cdot \frac{434,78}{2,7} = 564\ mm$

Minimal anchorage length:

$l_{b,min} = max(0{,}3 l_{b,req};\ 10\phi;\ 100mm)$

For $\phi 10$: $l_{b,min} = max(0{,}3 \cdot 403;\ 100\,mm;\ 100\,mm) = 121\ mm$

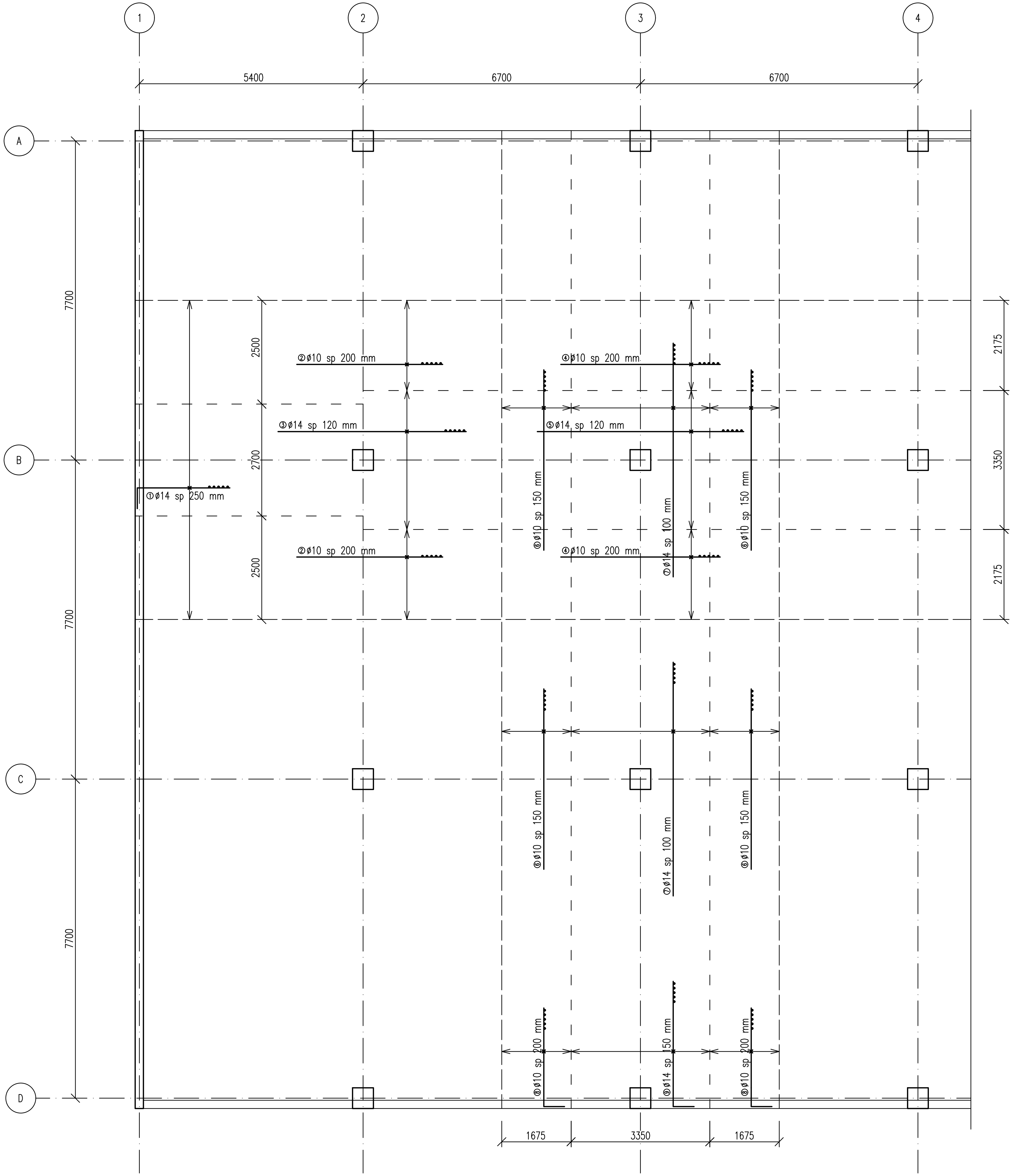
For $\phi 14$: $l_{b,min} = max(0{,}3 \cdot 564;\ 140\,mm;\ 100\,mm) = 169\ mm$

Design anchorage length: $l_{b,d} = max(\alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot l_{b,req};\ l_{b,min})$

(assume $\alpha_i = 1$)

For $\phi 10$: $l_{b,d} = max(403\,mm;\ 121\,mm) = 403\,mm$

For $\phi 14$: $l_{b,d} = max(564\,mm;\ 169\,mm) = 564\,mm$



LIST OF REINFORCEMENT:

1ø14; L = 2460 mm (570 / 1890)

2ø10; L = 3320 mm (3320)

3ø14; L = 4260 mm (4260)

4ø10; L = 3600 mm (3600)

5ø14; L = 4640 mm (4640)

6ø10; L = 4100 mm (4100)

7ø14; L = 5300 mm (5300)

8ø10; L = 2710 mm (410 / 2300)

9ø14; L = 3470 mm (570 / 2900)

MATERIALS:

CONCRETE C24/30

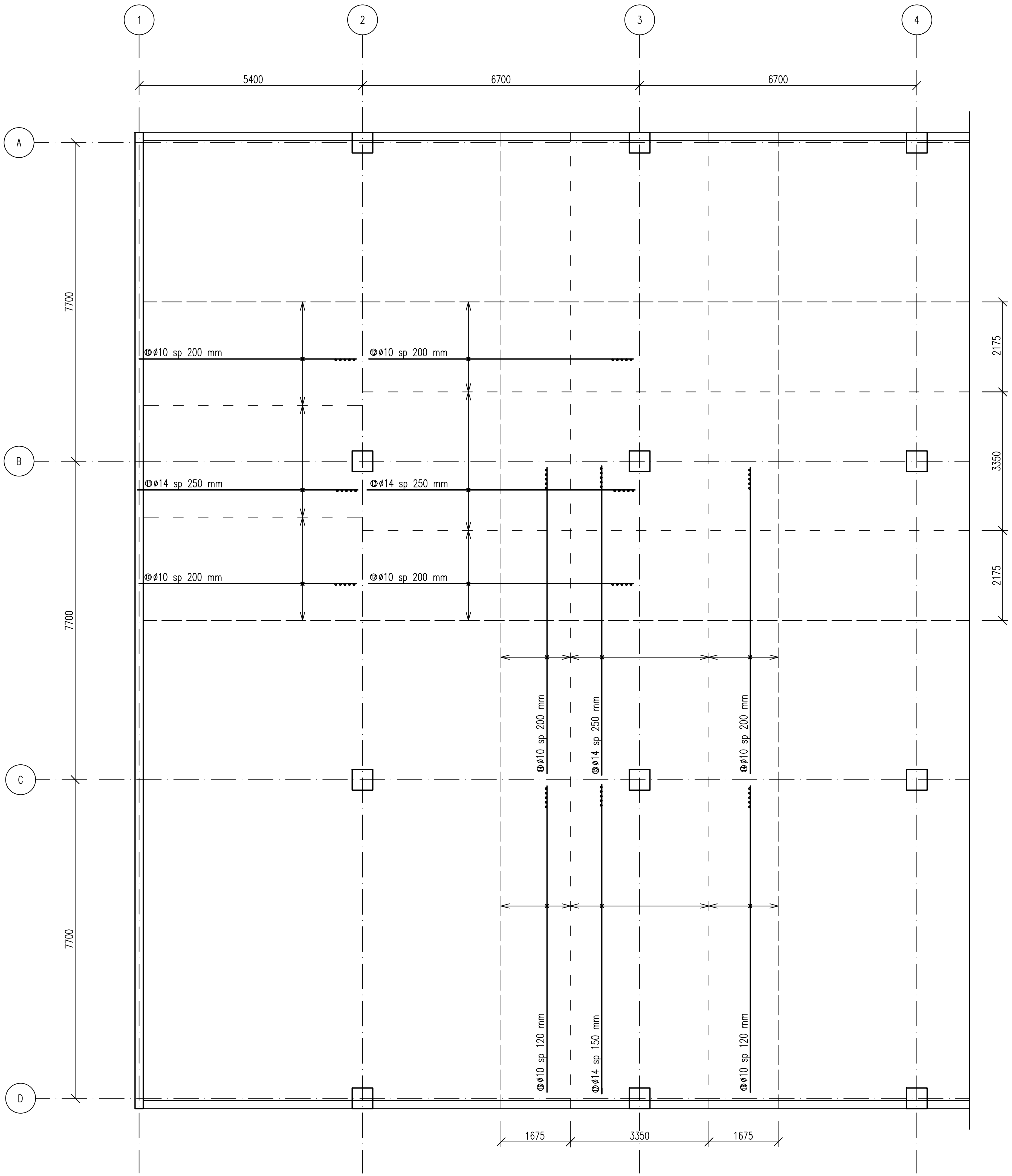
STEEL B500B

ANCHORAGE:

FOR ø10 – min. 403 mm

FOR ø14 – min. 564 mm

STUDENT: DARINA PONOMARENKO			
TEACHER: ING. JAKUB HOLAN			
COURSE: 133CM01		FORMAT:	A3
		SCALE:	1:100
CONTENT: SLAB REINFORCEMENT		DATE:	11/2024
		ASSIGNMENT:	3



LIST OF REINFORCEMENT:

⑩ø10; L = 5250 mm — 5250

⑪ø14; L = 5330 mm — 5330

⑫ø10; L = 6400 mm — 6400

⑬ø14; L = 6480 mm — 6480

⑭ø10; L = 7400 mm — 7400

⑮ø14; L = 7480 mm — 7480

⑯ø10; L = 7400 mm — 7400

⑰ø14; L = 7480 mm — 7480

MATERIALS:

CONCRETE C24/30

STEEL B500B

ANCHORAGE:

FOR ø10 – min. 403 mm

FOR ø14 – min. 564 mm

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Design of punching reinforcement

1. Failure at u_0 perimeter

– was checked in hw 7

2. Failure at u_1 perimeter

Checking if the slab can carry the load without punching reinforcement

$$v_{Ed,1} \leq v_{Rd,c}$$

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

$$u_1 = 5,38\,m$$

$$d = \frac{d_c + d_3}{2} = \frac{255 + 268}{2} = 261,5 \text{ mm}$$

$$=> v_{Ed,1} = \frac{1,15 \cdot 1001,24}{5,38 \cdot 0,2615} = 818,4 \text{ kPa}$$

$$v_{Rd,c} = \max\left(C_{Rd,c} \cdot k \sqrt[3]{100 \rho_l \cdot f_{ck}} ;\ 0,035 \sqrt{k^3 \cdot f_{ck}}\right)$$

$$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{261,5}} = 1,875 < 2 \ \checkmark$$

$$\rho_l = \sqrt{\rho_{lc} \cdot \rho_{l3}} \leq 0,2$$

$$\rho_{lc} = \frac{a_{sc}}{1000 \cdot d_c} = \frac{1283}{1000 \cdot 255} = 0,005$$

$$\rho_{l3} = \frac{a_{s3}}{1000 \cdot d_c} = \frac{1539}{1000 \cdot 268} = 0,006$$

$$=> \rho_l = \sqrt{0,005 \cdot 0,006} = 0,0055$$

$$=> v_{Rd,c} = \max\left(0,12 \cdot 1,875 \cdot \sqrt[3]{100 \cdot 0,0055 \cdot 25} ;\ 0,035 \sqrt{1,875^3 \cdot 25}\right) =$$

$$= \max(0,54; 0,45) = 0,54 \text{ MPa} = 540 \text{ kPa}$$

$$818,4 > 540$$

We must design punching reinforcement

3. Design

$$u_{out} = \frac{\beta \cdot V_{Ed}}{v_{Rd,c} \cdot d} = \frac{1{,}15 \cdot 1001{,}24}{540 \cdot 0{,}2615} = 8{,}15 \text{ m}$$

$$r_{out} = \frac{u_{out}}{2\pi} = \frac{8{,}15}{2\pi} = 1{,}3 \text{ m}$$

1) first stud $< (0{,}3 - 0{,}5)d = (78{,}45 - 130{,}75)$ mm from column face

2) last stud $< 1{,}5\,d = 392{,}25$ mm from u_{out}

3) radial spacing $S_r \leq 0{,}75\,d = 196{,}25$ mm

4) tangential spacing of last studs $S_t \leq 2d = 523$ mm

5) tangential spacing of studs in $u_1 < 1{,}5d = 392{,}25$ mm

Number of bars:

$$n \geq \max\left(\frac{2\pi(r_{out} - 1{,}5d)}{2d}; \frac{u_1}{1{,}5d}\right) = \max\left(\frac{2\pi(1300 - 392{,}25)}{523}; \frac{5380}{392{,}25}\right) =$$

$$= \max(10{,}9; 13{,}7) \Rightarrow n = 15$$

Design $16\,\phi_{sw}\,10$

$$A_{sw} = n A_{sw,1} = n\left(\pi \cdot \frac{\phi_{sw}^2}{4}\right) = 16\left(\frac{\pi \cdot 10^2}{4}\right) = 1257 \text{ mm}^2$$

4. Load-bearing capacity

$$V_{Rd,cs} = \min\left(0{,}75 \cdot V_{Rd,c} + \frac{1{,}5 \cdot A_{sw} \cdot f_{yd}}{S_r \cdot u_1}; k_{max} \cdot V_{Rd,c}\right) =$$

$$= \min\left(0{,}75 \cdot 540 + \frac{1{,}5 \cdot 1257 \cdot 10^{-6} \cdot 434{,}78 \cdot 10^3}{0{,}18 \cdot 5{,}38}; 1{,}8 \cdot 540\right) =$$

$$= \min(1251{,}5 \text{ kPa}; 972 \text{ kPa}) = 972 \text{ kPa}$$

$972 > 818{,}4$ ✓

5. Detailing rules

$$\phi_{sw} \geq \phi_{sw,min}$$

$$\rho_{sw} = \frac{1{,}5 \cdot \pi \cdot \frac{\phi_{sw}^2}{4}}{S_r \cdot S_t} = \frac{1{,}5\pi \cdot \frac{10^2}{4}}{180 \cdot 500} = 0{,}0013$$

$$\rho_{sw,min} = \frac{0{,}08 \cdot \sqrt{f_{ck}}}{f_{yk}} = \frac{0{,}08\sqrt{25}}{500} = 0{,}0008$$

$0{,}0013 > 0{,}0008$ ✓