Assignment 10 & 11

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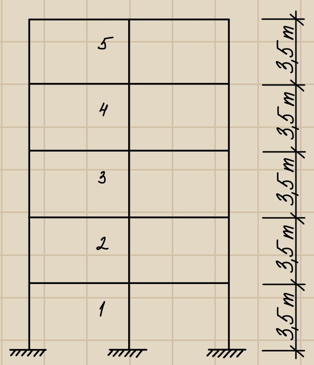
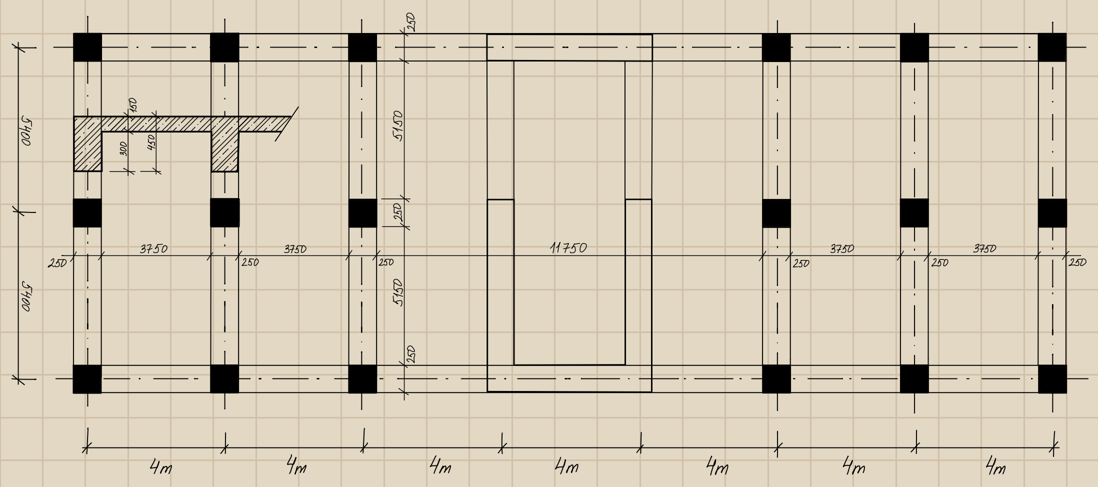




Input data:

$h = 3500$ mm – floor height

$h_s = 150$ mm – main slab

$h_f = 100$ mm – floor structure

$h_c = 20$ mm – cladding

1. Geometry design

Ideal $h_{st} = 170$ mm

$3500/170 = 20{,}6 \Rightarrow 22$ steps $\Rightarrow$ 2 flights with 11 steps

$$h_{st} = \frac{3500}{22} = 159 \text{ mm}$$

$b_{st} = 630 - 2h_{st} = 312$ mm

Design 2×11 159/312 steps

Alternative design (based on my memory of BSD course)

$h_{st} = (150 \sim 180 \text{ mm}) \Rightarrow$ take 180 mm

$3500/180 = 19{,}4 \Rightarrow 20$ steps

$$h_{st} = \frac{3500}{20} = 175 \text{ mm} ; \; b_{st} = 630 - 2h_{st} = 280 \text{ mm}$$

Design 2×10 175/280 mm steps

Flight width $= 1100\ mm \geq 1100\ mm$ ✓

Gap between the flights $= 200\ mm \geq 200\ mm$ ✓

Landing width $= 1200\ mm \geq 1100\ mm$ ✓

Total staircase width $= 2 \cdot 1100 + 200 = 2400\ mm$

Slope $\alpha = arctg\left(\frac{175}{280}\right) = 32°$ $\quad 25° \leq \alpha \leq 35°$ ✓

Length of flight $= 280 \cdot 10 = 2800\ mm$

Preliminary slab depth check:

the staircase is considered as a one-way slab of span $2800 + 1200 =$

$= 4000\ mm$.

* staircase slab

$h_{ss}^{*}; h_s \geq \frac{4000}{25} = 160\ mm$

We can already tell that main slab is too thin => preliminarily increase $h_s = 200\ mm$

$\Rightarrow h_{ss} = 206\ mm$ — this thickness is not arbitrarily chosen but given by the main slab thickness and staircase geometry, see drawing at the end of the HW.

$200\ mm > 160\ mm$; $206\ mm > 160\ mm$ ✓

Perpendicular and head clearance

a) head clearance:

$$h_1 > 1500 + \frac{750}{\cos\alpha} = 1500 + \frac{750}{\cos 32°} = 2384\ mm$$

$$h_1 > 2100\ mm$$

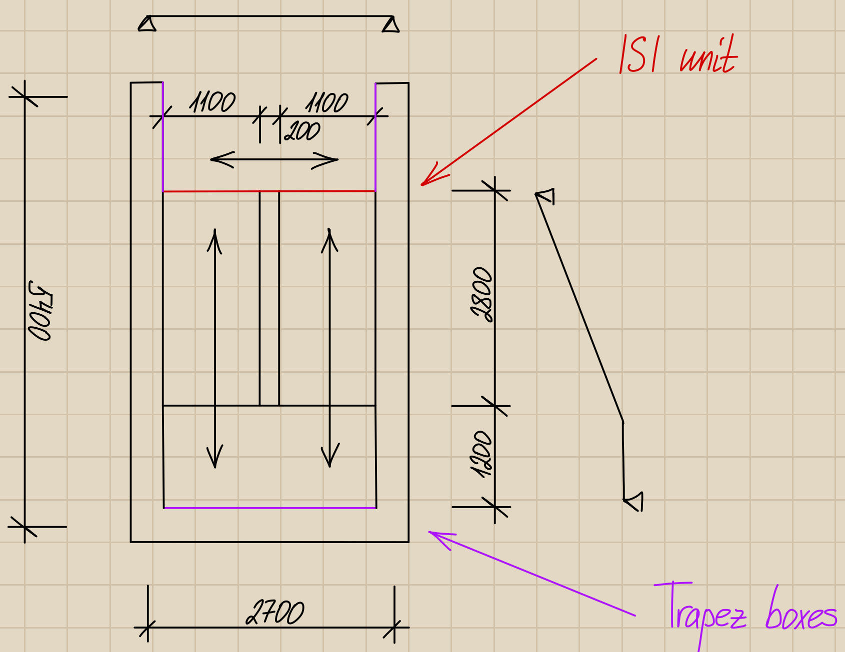
$$h_1 = h - h_s - h_f - h_{st} = 3500 - 200 - 150 - 175 = 2975\ mm \checkmark$$

b) perpendicular clearance:

$$h_2 > 750 + 1500 \cdot \cos\alpha = 750 + 1500 \cdot \cos 32° = 2022\ mm$$

$$h_2 > 1900\ mm$$

$$h_2 = h_1 \cdot \cos\alpha = 2975 \cdot \cos 32° = 2523\ mm \checkmark$$



2. Loads

a) landing

Load	k-value [kN/m²]	γ	d-value [kN/m²]
Slab	$0{,}2 \cdot 25 = 5$	1,35	6,75
Floor	1	1,35	1,35
Live load	3,5	1,5	5,25

$f_{dL} = 13{,}35\ kN/m^2$

b) flight

Load	k-value [kN/m²]	γ	d-value [kN/m²]
Slab	$0{,}242^{*} \cdot 25 = 6{,}05$	1,35	8,17
Cladding	$\frac{175+280}{280} \cdot \frac{1}{2} = 0{,}81$	1,35	1,09
Steps	$0{,}5 \cdot 0{,}175 \cdot 25 = 2{,}2$	1,35	2,97
Live load	3,5	1,5	5,25

$f_{df} = 17{,}48\ kN/m^2$

* vertically measured thickness of the flight slab

Converting to linear loads:

$f_{dl,lin} = 13{,}35 \cdot 1{,}1 = 14{,}69\ kN/m$

$f_{df,lin} = 17{,}48 \cdot 1{,}1 = 19{,}56\ kN/m$

3. Internal forces (conservative estimation)

$$M_{Ed} = \frac{f_d \cdot l^2}{12} = \frac{19{,}56 \cdot 4^2}{12} = 26{,}08 \text{ kNm}$$

Assignment 11

4. Design of reinforcement

$$d_{ss} = h_{ss} - c - \frac{\phi}{2}$$

For rebars up to 14 mm => $c = 25$ mm

Take $\phi = 10$ mm

$$d_{ss} = 206 - 25 - 5 = 176 \text{ mm}$$

$$\frac{kN\cancel{m}}{\cancel{m} \cdot \frac{kN}{m^2}} \times 10^6 = m^2 \cdot 10^6 = mm^2$$

$$A_{s,rqd} = \frac{M_{Ed}}{z \cdot f_{yd}} = \frac{M_{Ed}}{0{,}9 d_{ss} \cdot f_{yd}} = \frac{25{,}04 \cdot 10^6}{0{,}9 \cdot 0{,}176 \cdot 434{,}78 \cdot 10^3} = 364 \text{ mm}^2$$

Design $6\phi 10$ => $A_{s,prov} = 6\pi \cdot 5^2 = 471 \text{ mm}^2$; $s_a = \frac{1100}{6} = 183$ mm

$$x = \frac{A_{s,prov} \cdot f_{yd}}{0{,}8 b_{ss} \cdot f_{cd}} = \frac{471 \cdot 434{,}78}{0{,}8 \cdot 1100 \cdot 16{,}67} = 14 \text{ mm}$$

$$z = d_{ss} - 0{,}4x = 176 - 0{,}4 \cdot 14 = 170 \text{ mm}$$

$$M_{Rd} = A_{s,prov} \cdot z \cdot f_{yd} = 471 \cdot 10^{-6} \cdot 0{,}17 \cdot 434{,}78 \cdot 10^3 = 34{,}81 \text{ kNm}$$

$34{,}81 > 25{,}04$ ✓

5. Detailing rules

a) $$\xi = \frac{x}{d_{ss}} = \frac{14}{176} = 0{,}08$$

$$\xi \leq \min\left(\xi_{bal,1} = \frac{700}{700 + f_{yd}}; 0{,}45\right) = \min(0{,}62; 0{,}45) = 0{,}45$$

$0{,}08 < 0{,}45$ ✓

b) $$A_{s,min} = \max\left(0{,}26 \cdot \frac{f_{ctm}}{f_{yk}} \cdot b_{ss} \cdot d_{ss}; 0{,}0013 b_{ss} \cdot d_{ss}\right) =$$

$$= \max\left(\frac{0{,}26 \cdot 2{,}6 \cdot 1{,}1 \cdot 0{,}176 \cdot 10^6}{500}; 0{,}0013 \cdot 1100 \cdot 176\right) =$$

$= \max(262\ mm^2; 252\ mm^2) = 262\ mm^2$

$471\ mm^2 > 262\ mm^2$ ✓

c) $A_{s,max} = 0{,}04\, b_{ss} \cdot d_{ss} = 0{,}04 \cdot 1100 \cdot 176 = 7744\ mm^2$

$471\ mm^2 < 7744\ mm^2$

d) $S_{a,max} = \min(2h_{ss}; 250\ mm) = \min(2 \cdot 206\ mm; 250\ mm) = 250\ mm$

$183\ mm < 250\ mm$ ✓

e) $S_{c,min} = \max(20\ mm; 1{,}2\phi) = \max(20\ mm; 12\ mm) = 20\ mm$

$S_c = 183 - 10 = 173\ mm$

$173\ mm > 20\ mm$ ✓

f) $\lambda = \frac{\ell}{d_{ss}} = \frac{4000}{176} = 22{,}73$ $\quad K_{c3} = \frac{500}{f_{yk}} \cdot \frac{A_{s,prov}}{A_{s,rqd}} = \frac{471}{388} = 1{,}2$

$\lambda \leq K_{c1} \cdot K_{c2} \cdot K_{c3} \cdot \lambda_{d,tab} = 1 \cdot 1{,}2 \cdot 24{,}1 = 28{,}92$

$22{,}73 < 28{,}92$ ✓

5. Secondary reinforcement

a) edge reinforcement

$l_{bd} \geq 2h_s = 400\ mm$

b) transverse reinforcement

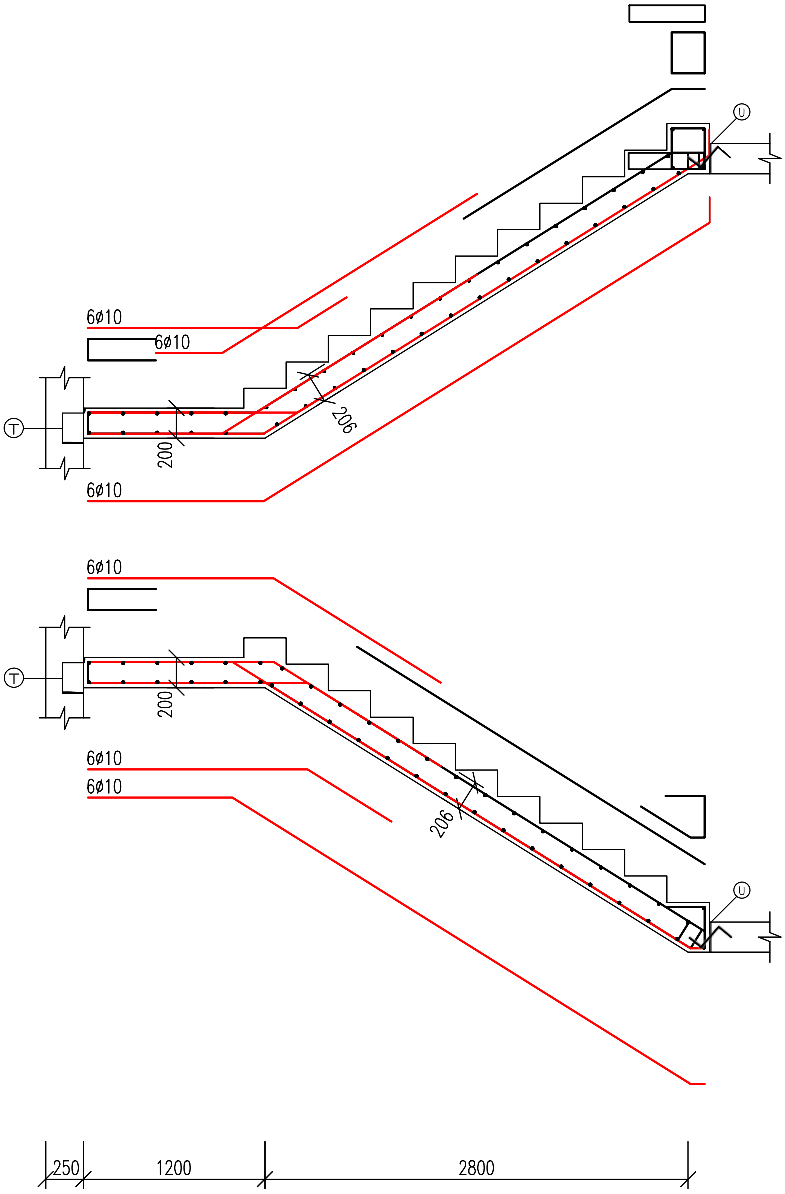
$\frac{471\ mm^2}{1{,}1\ m} = 428\ mm^2/m$

$a_{s,tr} \geq 0{,}25\, a_{s,main} = \frac{0{,}25 \cdot 471}{1{,}1} = 107\ mm^2/m$

$S_{tr} \leq \min(3h; 400\ mm) = \min(600\ mm; 400\ mm) = 400\ mm$

Design $\phi 6$ per $200\ mm \Rightarrow a_{s,tr} = 141\ mm^2/m$

$S_{tr} = \frac{1200}{5} = 240\ mm$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200
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250
1200
2800