HOMEWORK 10-CM01

Engin Aydeniz
Erasmus student

TASK 5: REINFORCED CONCRETE STAIRCASE

1. Design of dimensions of reinforced concrete staircase

Assignment

→ Height of the floor $h_k = 3700$ mm
→ Depth of the main slab $h_s = 210$ mm
→ Depth of floor structur $h_f = 150$ mm
→ Thickness of cladding of the stair $h_c = 30$ mm

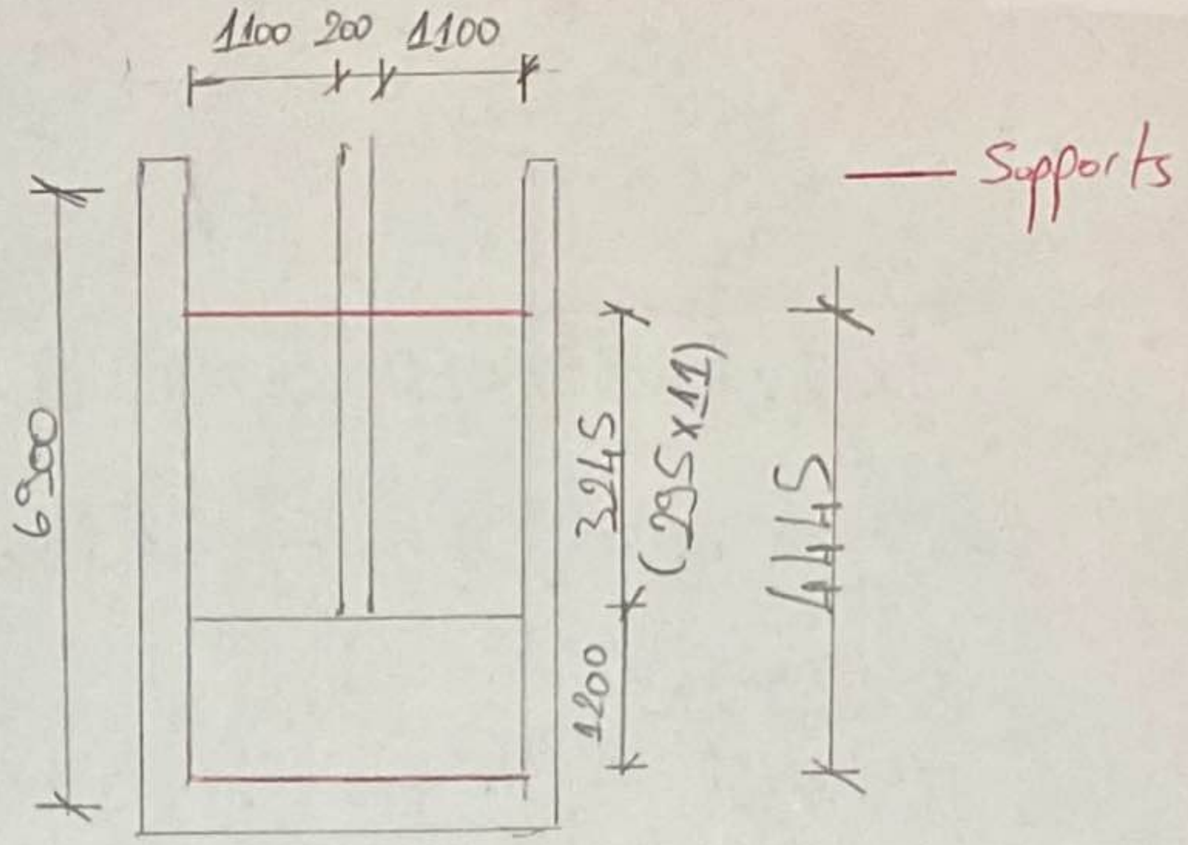
Dimensions of the staircase

→ Ideal height of one step is 170 mm
→ 3700/170 ≈ 21,76 → 22 steps (2 flights with 11 steps)
→ Height of one step $h = 3700/22 = 168$ mm
→ Width of one step $b = 630 - 2h = 630 - 2 \times 168 = 294$ mm

⇒ DESIGN: Staircase with 168/295 mm steps, 2 flights, 11 steps in each flight

→ Width of the flight – 1100 mm (in general, 1100 mm is the minimum width of the flight)
→ Width of the gap between the flights – 200 mm (common value)
→ Width of the landing – 1200 (should be at least "width of the flight + 100 mm)
→ Width of the staircase is $1100 \times 2 + 200 = 2400$ mm
→ Slope of the staircase is $\alpha = \arctan(168/295) \approx 29,66°$

Scheme of the staircase



Preliminary check of the depth of th slab

- The staircase is considered as one way slab with span of 4445 mm. The slab will be supported => the depth should be at least 4445/25 = 177,8 mm
- The depth of landings is the same as the depth of the main slab 210 mm.
- The depth of flights : 199 mm

210 mm > 177,8 mm and 199 mm > 177,8 mm OK!

Perpendicular and head clearance of the staircase

- Head clearance of the staircase shald be more than $1500 + \frac{750}{\cos\alpha}$

$= 1500 + \frac{750}{\cos(29,66)} \simeq 2363$ mm and more than 2100 mm

- Head clearance of our staircase is $h_1 = h_k - h_s - h_f - h$

$\Rightarrow h_1 = 3700 - 210 - 150 - 168$

3172 mm > 2363 OK!

- Perpendicular clearance of the staircase should be more than.

$750 + 1500 \times \cos\alpha = 750 + 1500 \times \cos(29,66) \simeq 2053$ mm and more than 1900 mm

- Perpendicular clearance of our staircase is $h_2 = h_1 \cos\alpha = 3172 . \cos(29,66)$

$= 2756$ mm

> 2053 mm OK!

2. Calculations of loads

Landing

Load	Char. value [kN/m²]	γ_F	Design value [kN/m²]
Slab	0,21 . 25 = 5,25	1,35	7,09
Floor	1	1,35	1,35
Live load	3,5	1,50	5,25

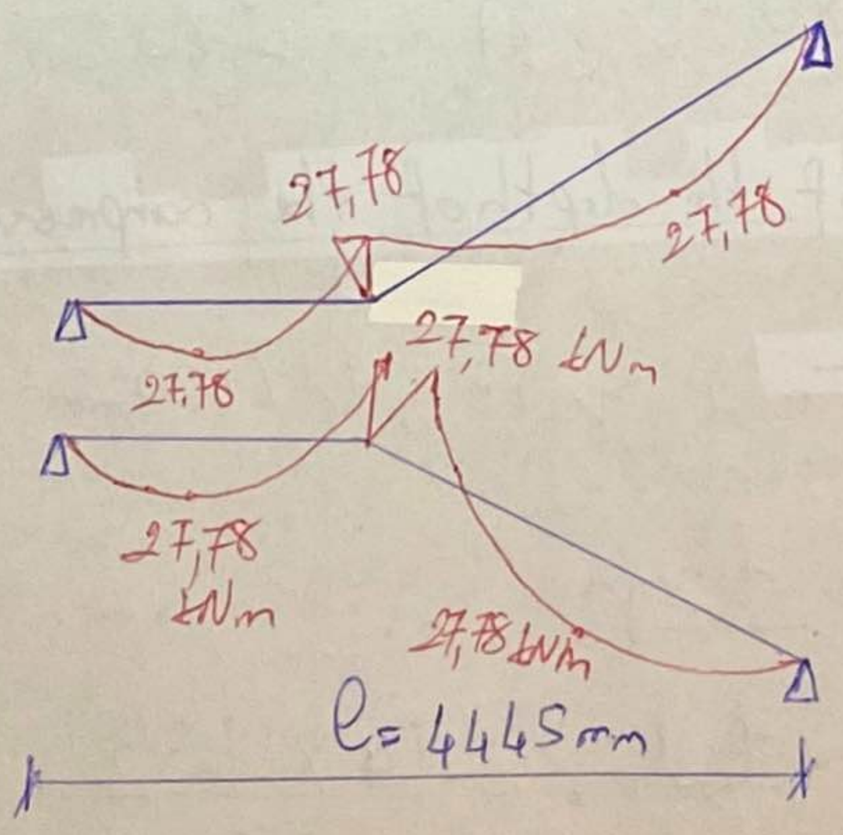
$f_d = 13,69$ kN/m²

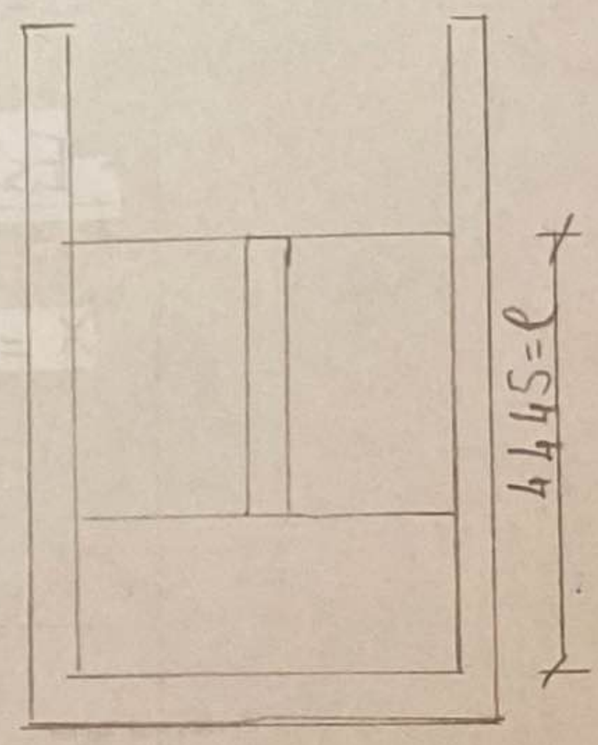
Flight

Load	Char. Value [kN/m²]	γ_F	Design Value [kN/m²]
slab	$\frac{0,199}{\cos(29,66)} \times 25$	1,35	7,73
Cladding	$0,5 \cdot \frac{168+295}{295}$	1,35	1,06
Steps	$\frac{0,168}{2} \cdot 25$	1,35	2,83
Live load	3,5	1,5	5,25

$f_{df} = 16,87$ kN/m²

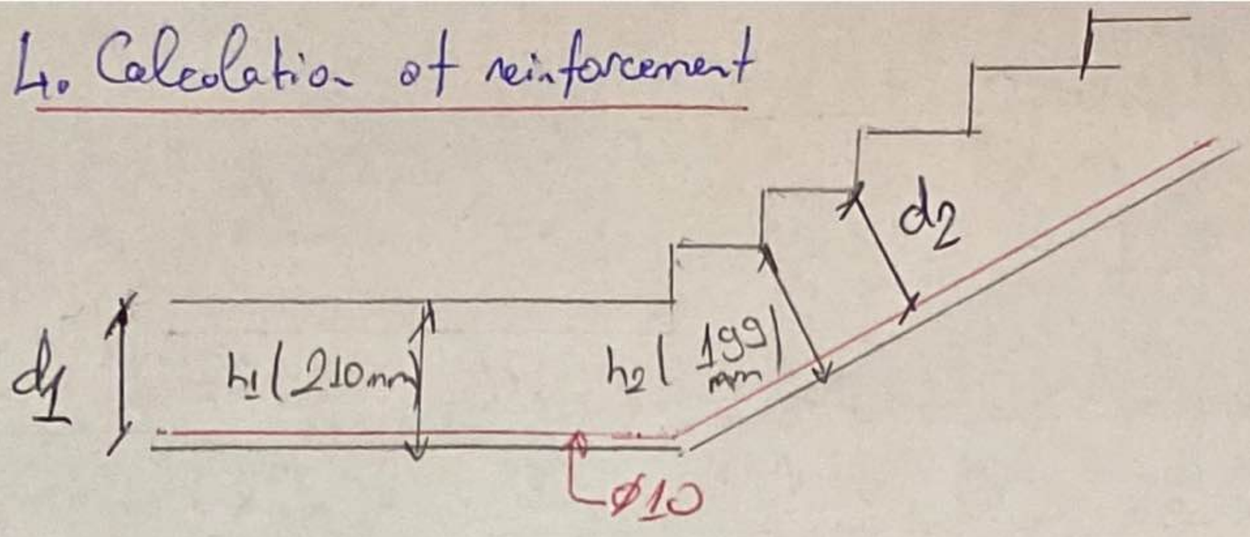
3. Design bending moment





$$M_{Ed} = \frac{1}{12} f_{df} \cdot l^2 = \frac{1}{12} \times 16,87 \times 4,445^2 \approx 27,78 \text{ kNm}$$

4. Calculation of reinforcement



$$d_1 = h_1 - c - \frac{\phi}{2} = 210 - 25 - \frac{10}{2} = 180 \text{ mm}$$

$$d_2 = h_2 - c - \frac{\phi}{2} = 199 - 25 - \frac{10}{2} = 169 \text{ mm}$$

We keep the smallest effective depth $\boxed{d = 169 \text{ mm}}$. Because we use the same reinforcement for the landing and flight. The smallest effective depth allows us to be conservative although it's not economic.

$$a_{s,rqd} = \frac{M_{Edmax}}{0,9 . d . f_{yd}} = \left(\frac{27,78 \times 10^3}{0,9 . 0,169 \times 435 \times 10^6} \right) \times 10^4 \simeq 4,20 \text{ cm}^2$$

This is the required area for 1 m of the flight.
But your flight is 1.1 m wide
So in fact, you need 4,20*1,1 = 4,62 cm2.
You designed 4,74 cm2, so it is still OK,
but be careful about this.

$$a_{s,min} = \max\left(0,26 \frac{f_{ctm}}{f_{yk}} . b_s . d_s ; \ldots . d_s\right)$$

$$= \max\left(0,26 \frac{2,9}{500} . 1,1 . 0,169 ; 0,0013 . 1,1 . 0,169\right) \times 1$$

$$= \max(2,80 ; 2,42) = 2,80 \text{ cm}^2 < a_{s,rqd} \text{ OK!}$$

DESIGN: ø10 with spacing of 183 mm (6xø10)

$a_{s,prov} = 474 \text{ mm}^2 > a_{s,rqd}$ (420 mm^2) OK!

Check of the design

$$x = \frac{a_{s,prov} . f_{yd}}{0,8 . b_s . f_{cd}} = \frac{474 \times 435}{0,8 . 1,1 \times 20 \times 10^6} \times 10^3 \simeq 11,71 \text{ mm}$$

$$z = d_B - 0,4x$$

$$= 169 - 0,4 . 11,71 \simeq 164,32$$

$$M_{Rd} = a_{s,prov} . f_{yd} . z = (474 \times 435 \times 0,16432) \times 10^{-3}$$

$33,88 \text{ kNm} > M_{Ed}$ ($27,78 \text{ kNm}$) OK!

5. Detailing rules

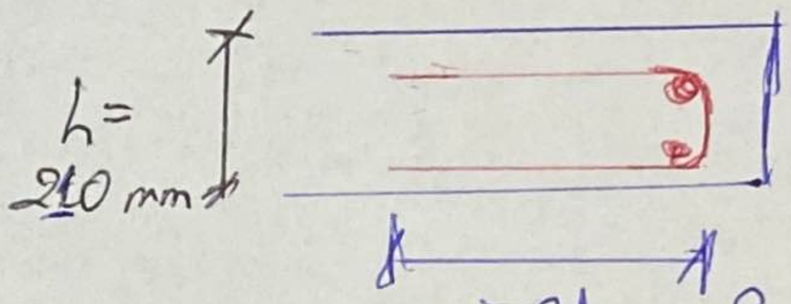
$$\xi = \frac{x}{d} = \frac{11,71}{169} = 0,069 < 0,45 \quad \text{OK!}$$

Spacing of rebers

$$s \leq s_{min}(2h_s ; 250\ mm)$$
$$\leq min(2 \times 183 ; 250\ mm) = 250\ mm > 183\ mm \quad \text{OK!}$$

6. Sketch of reinforcement

Edge reinforcement



Transverse reinforcement

$$a_{s,tr} \geq 0,25 \cdot a_{s,main}$$
$$\geq 0,25 \times 476 \approx 119\ mm^2/m$$

$$s_{tr} \leq min(3h ; 600\ mm)$$
$$\leq min(3 \times 210 ; 600\ mm) = 600\ mm$$

DESIGN: $\phi 8$ with spacing of 600 mm

$a_{s,provider} = 125\ mm^2 > a_{s,tr}(119\ mm^2/m)$

$(\frac{1000}{4} \times 50 mm^2)$ OK!