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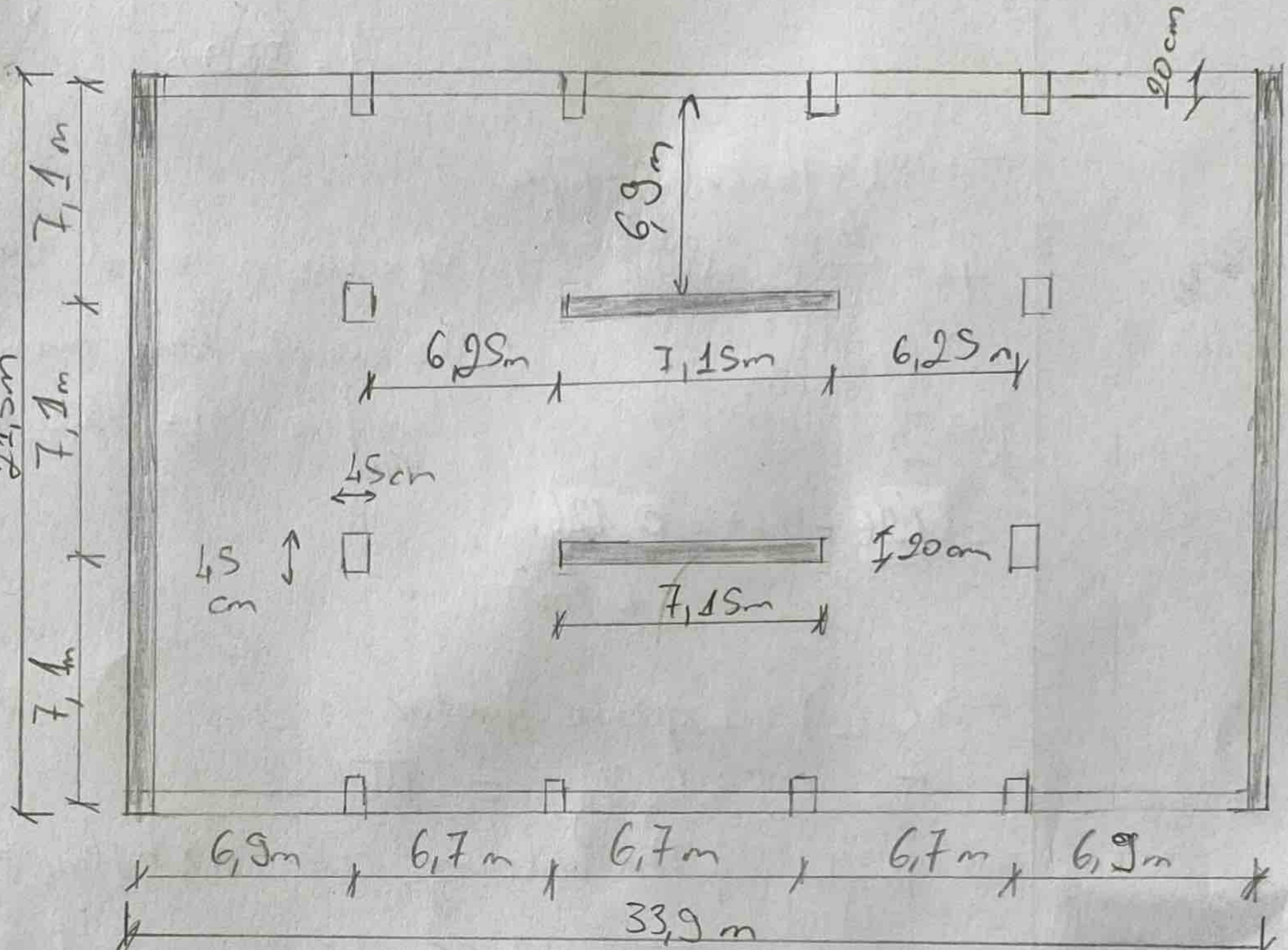
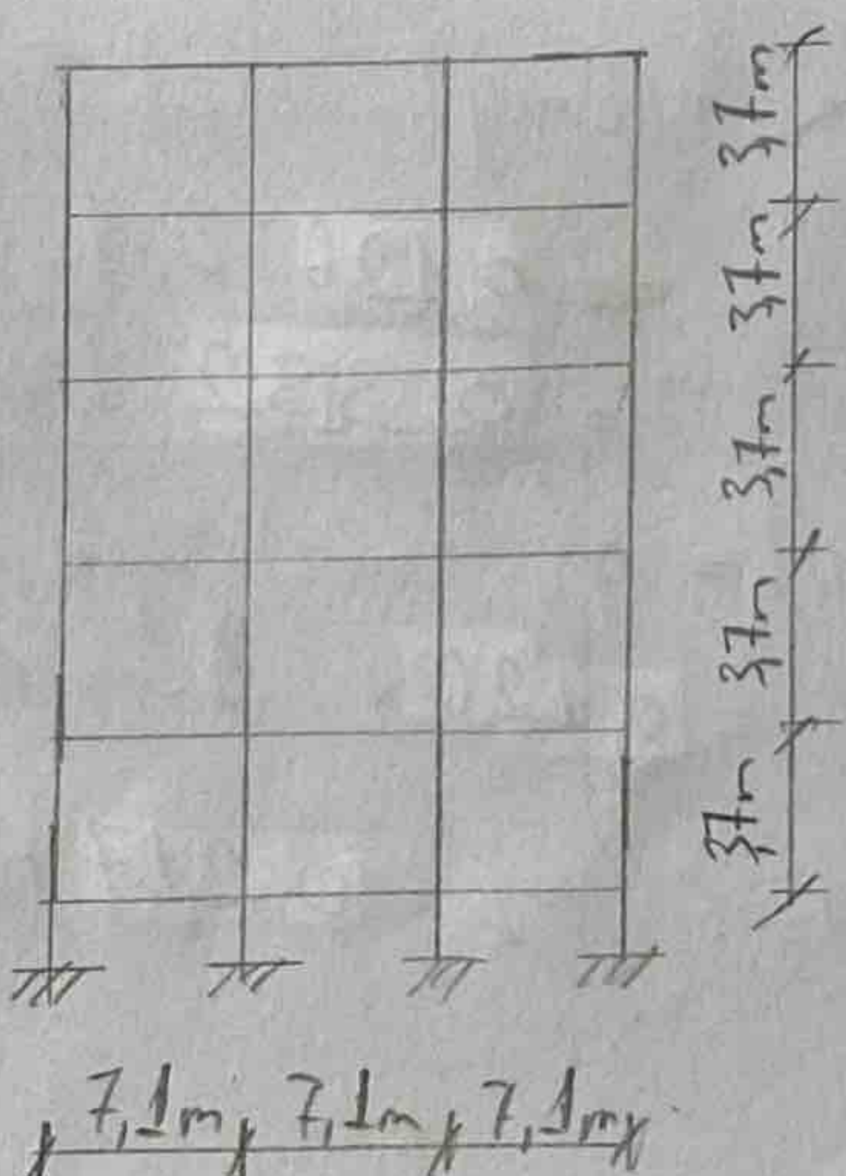
TASK 4 : Reinforced concrete stiffening walls

Input data



Elevation view



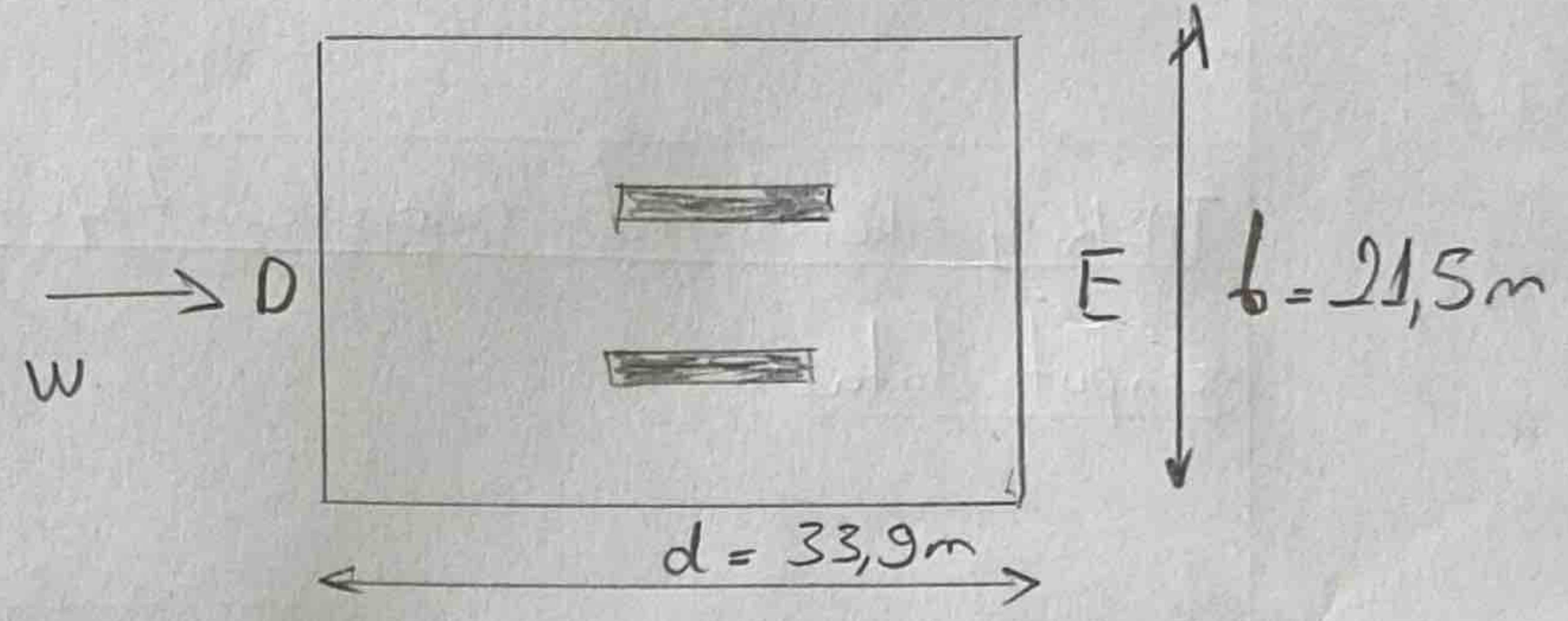
Terrain category : III
Wind load area : I

slab thickness = 28 cm

$(g-g_0)$ floor, k = 1,6 kN/m²
q floor, k = 3,9 kN/m²

f_{cd} = 20 MPa C30/37

1. Wind loads



→ $w_k = q_b \cdot c_e(z) \cdot c_{pe}$

$q_b = \frac{1}{2} \rho_v \cdot v_b^2$; | v_b = basic wind velocity
We are in load area I
Therefore $v_b = 22,5$ m/s

$q_b = \frac{1}{2} \cdot 1,25 \cdot 22,5^2$

$\simeq 316$ N/m² = 0,316 kN/m²

→ $C_e(z)$: Exposure factor
Terrain category = III
Height of the building $z = n \times h_{floor} = 5 \times 3,7 = 18,5$ m
For curve III and z = 18,5 m chart indicates a C_e which is 2,15

For the facade D : $w_k = q_b \cdot c_e(z) \cdot c_{pe}$
$= 0,316 \cdot 2,15 \cdot 0,8$
$= 0,543$ kN/m²

For the facade E : $w_k = q_b \cdot c_e(z) \cdot c_{pe}$
$= 0,316 \times 2,15 \times 0,5 \simeq 0,340$ kN/m²

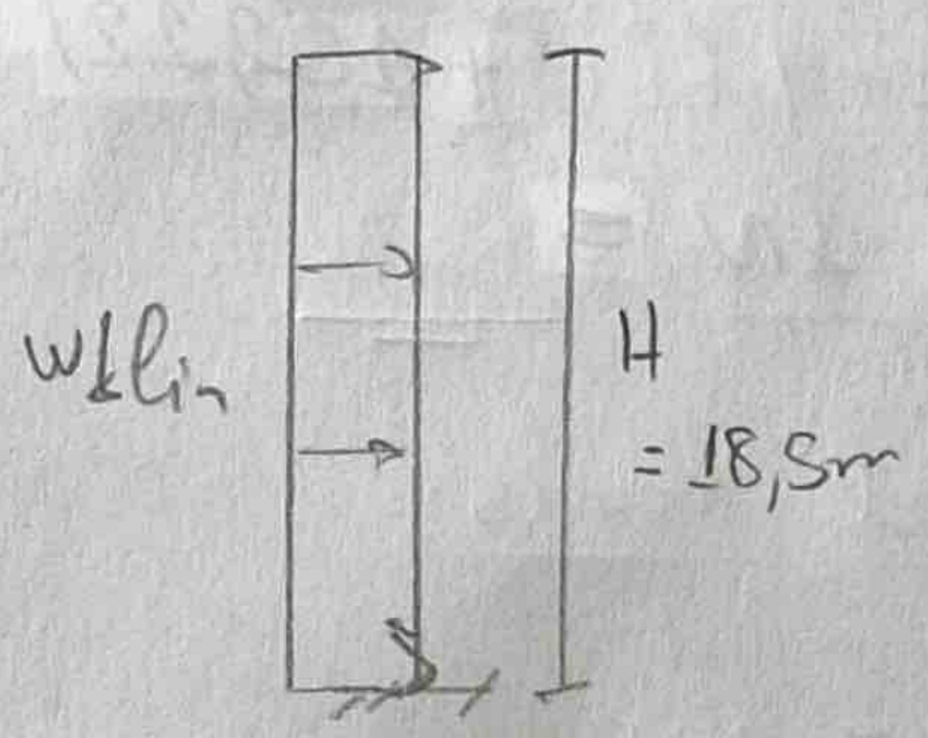
Sum of 2 winds loads : $w_k = 0,543 + 0,340 = 0,883$ kN/m²

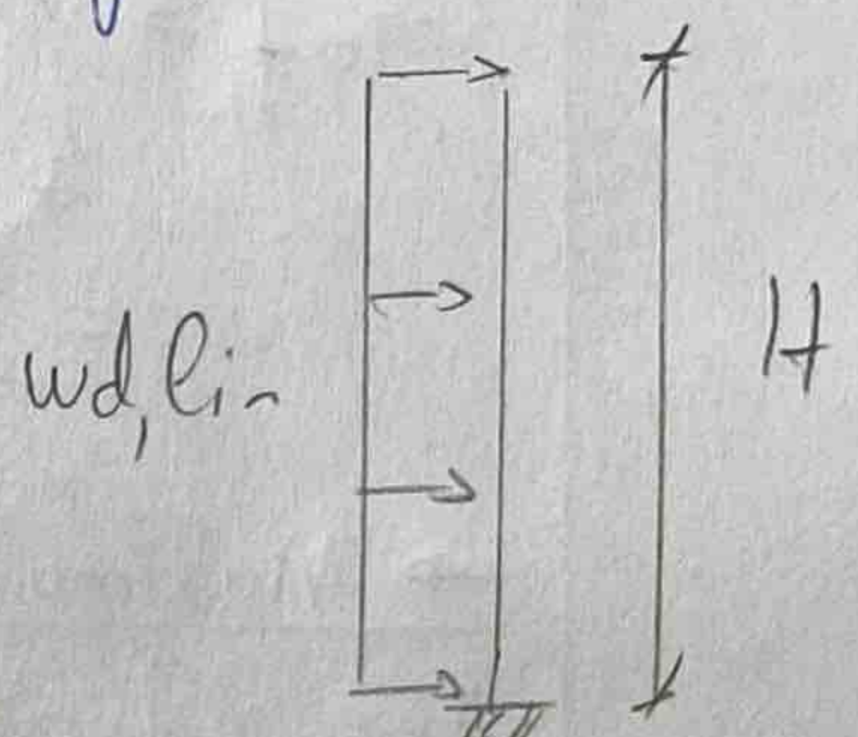
Design value of wind load

$w_d = \gamma_Q \cdot w_k$

$= 1{,}5 \cdot 0{,}883 = \underline{1{,}324 \text{ kN/m}^2}$

Linear characteristic and design load





$w_{k,lin} = w_k \cdot B$

$= 0{,}883 \cdot 21{,}5$

$= \underline{18{,}98 \text{ kN/ml}}$

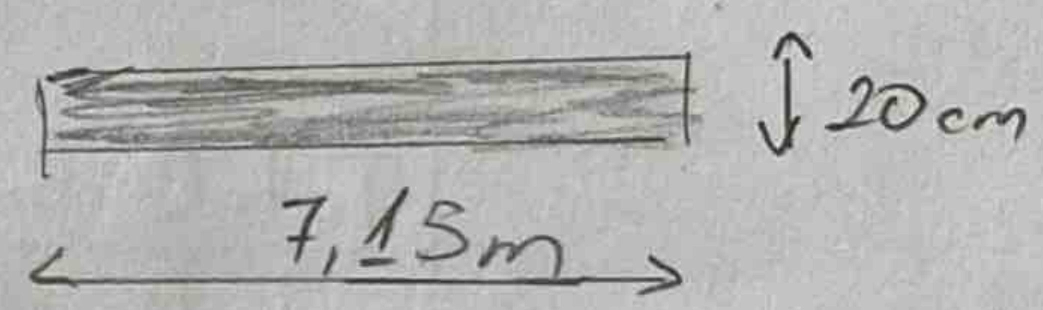
$w_{d,lin} = w_d \cdot B$

$= 1{,}324 \cdot 21{,}5$

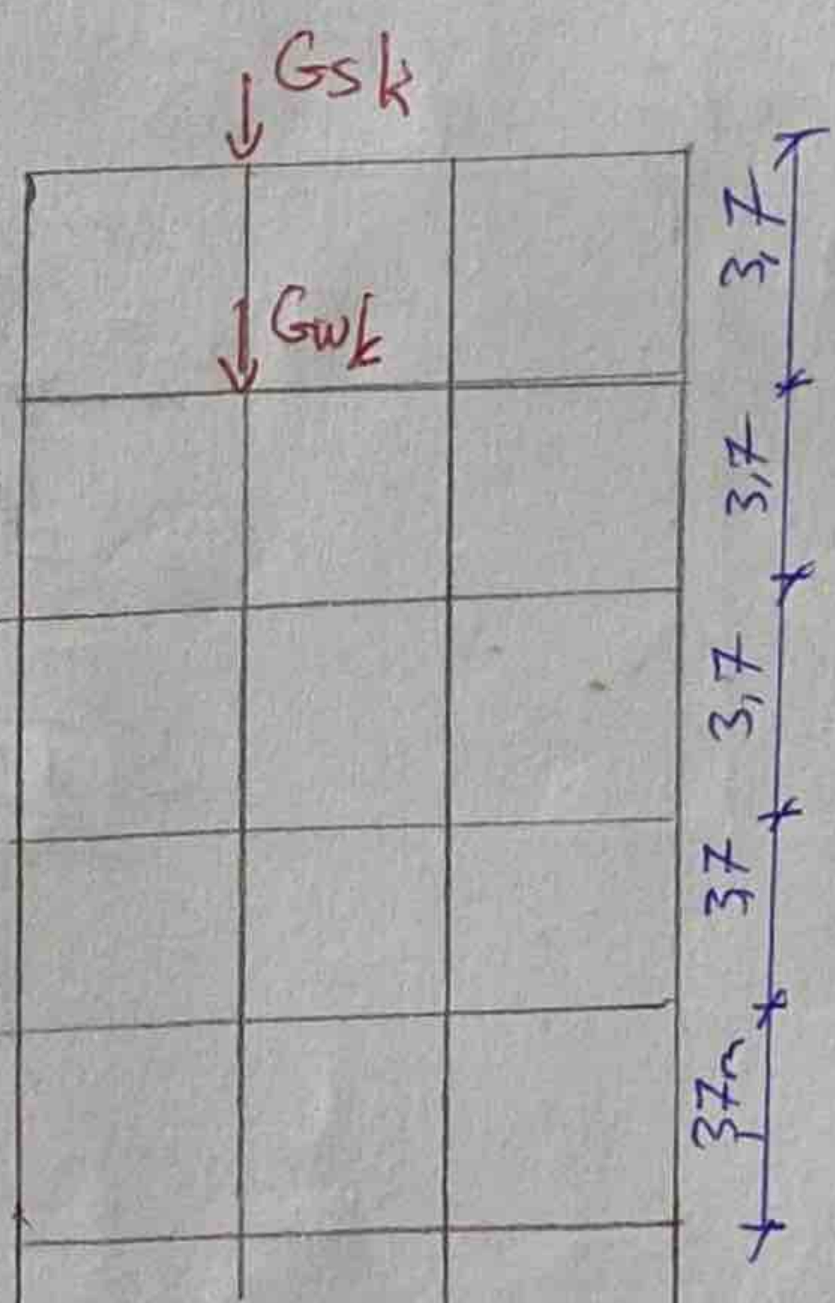
$= \underline{28{,}47 \text{ kN/ml}}$

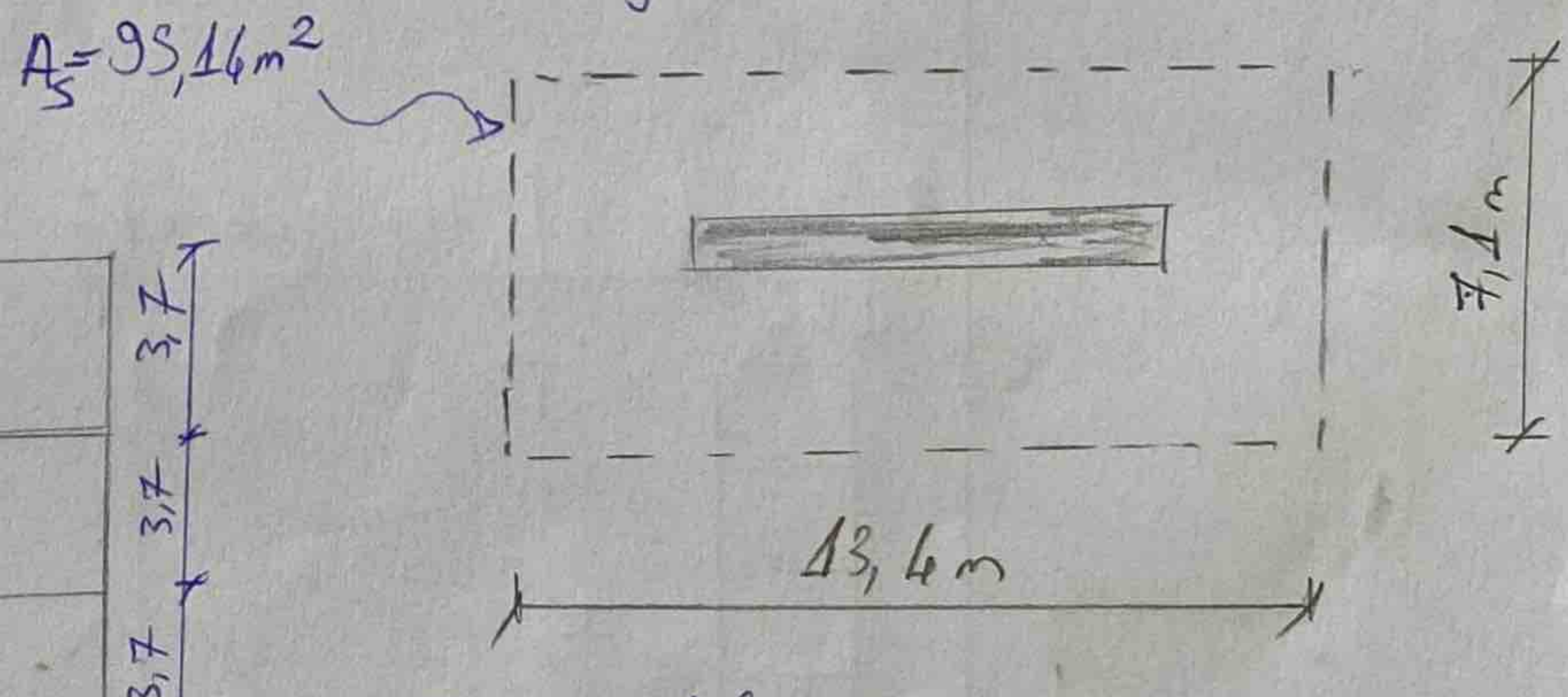
2. Vertical loads

1st estimation of wall:



*Minimum vertical load = Characteristic self-weigh from tributary area:





For 1 floor

wall: $G_{wk} = \rho_c \cdot t_w \cdot l_w \cdot h$

$= 25 \cdot 0{,}20 \cdot 7{,}15 \cdot 3{,}7$

$\simeq \underline{132{,}27 \text{ kN}}$

slab: $G_{sk} = \rho_c \cdot t_s \cdot A_s$

$= 25 \cdot 0{,}28 \cdot 95{,}14 \simeq \underline{666 \text{ kN}}$

~~• Permanent load (g-go) floor~~

~~$G_{f,k} = (g-go) floor,k \times A$~~

~~$= 1,6 \times 95,14 = 152,22$ kN~~

Total load at the bottom of building

$G_{Tot,k} = n \times (G_{w,k} + G_{s,k})$

$5 \times (132,27 + 666)$

$= 3991,35$ kN $= R_{min}$

→ Maximum vertical loads:

For 1 floor:

Wall: $G_{w,k} = 132,27$ kN

Slab: $G_{s,k} = 666$ kN

Permanent floor: $G_{F,k} = (g-go)_{floor,k} \times A$

$= 1,6 \times 95,14 = 152,22$ kN

Variable load: $Q_{F,k} = q_{floor,k} \times A$

$= 3,9 \times 95,14 \simeq 371,05$ kN

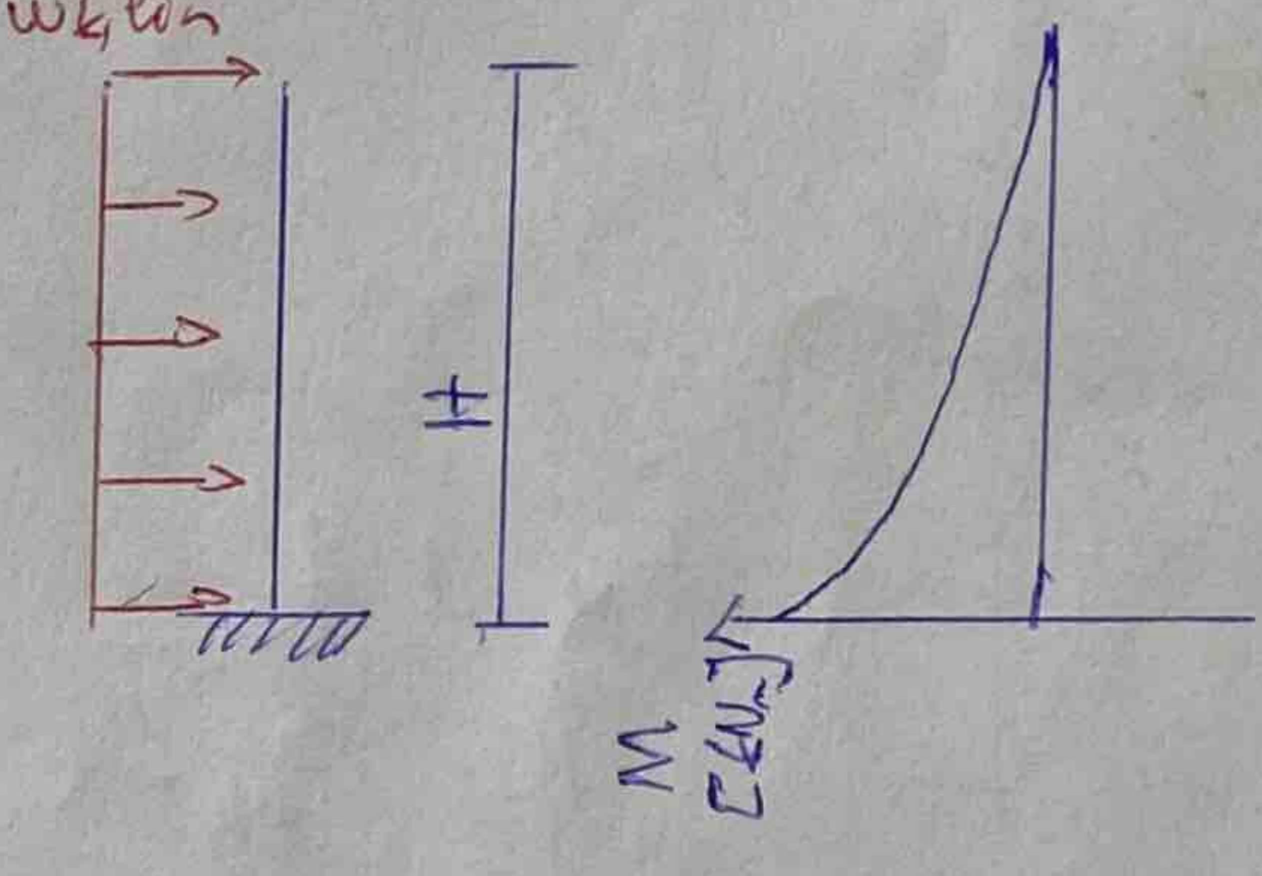
Total load of design at the bottom of building

$F_{T,d} = n \times [(\gamma_g . \Sigma G) + (\gamma_q . \Sigma Q)]$

$= 5 \times [(1,35.(132,27 + 666 + 152,22)) + (1,5 \times 371,05)]$

$F_{T,d} = 9198,68$ kN $= R_{max}$

3. Check of the geometry of walls



$M_w = \frac{1}{2} w_{k,lin} . H^2$

$= \frac{1}{2} . 18,98 . 18,5^2$

$\simeq 3248$ kNm

Stress from characteristic wind load:

$$\sigma_w = \frac{1}{m} \cdot \frac{M_w}{W} = \frac{1}{2} \cdot \frac{3248 \times 10^3}{\frac{1}{6} \cdot 9{,}20 \cdot 7{,}15^2} \times 10^{-3}$$

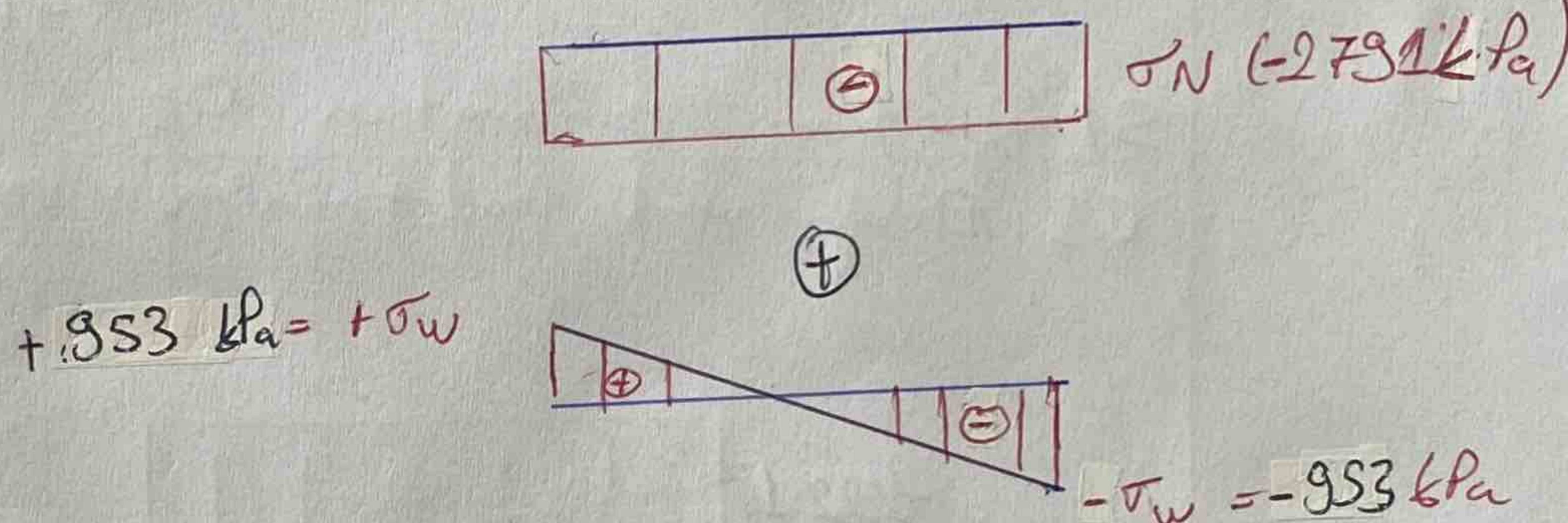
$$\simeq \pm 953 \text{ kPa}$$

Stress from the minimum vertical load

$$\sigma_N = \frac{-R_{min}}{A} = \frac{3991{,}35 \times 10^3}{9{,}2 \cdot 7{,}15} \times 10^{-3} \simeq -2791 \text{ kPa}$$

compression

Total stress in the foot of one stiffening wall



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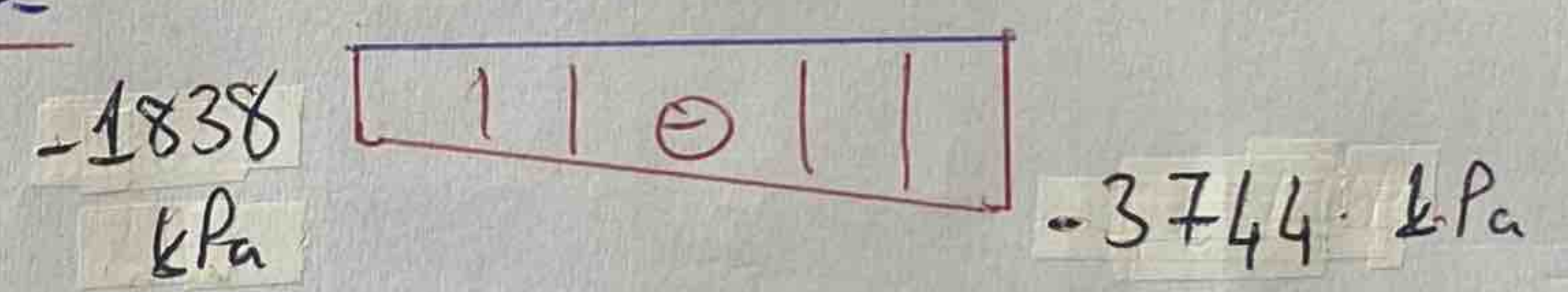
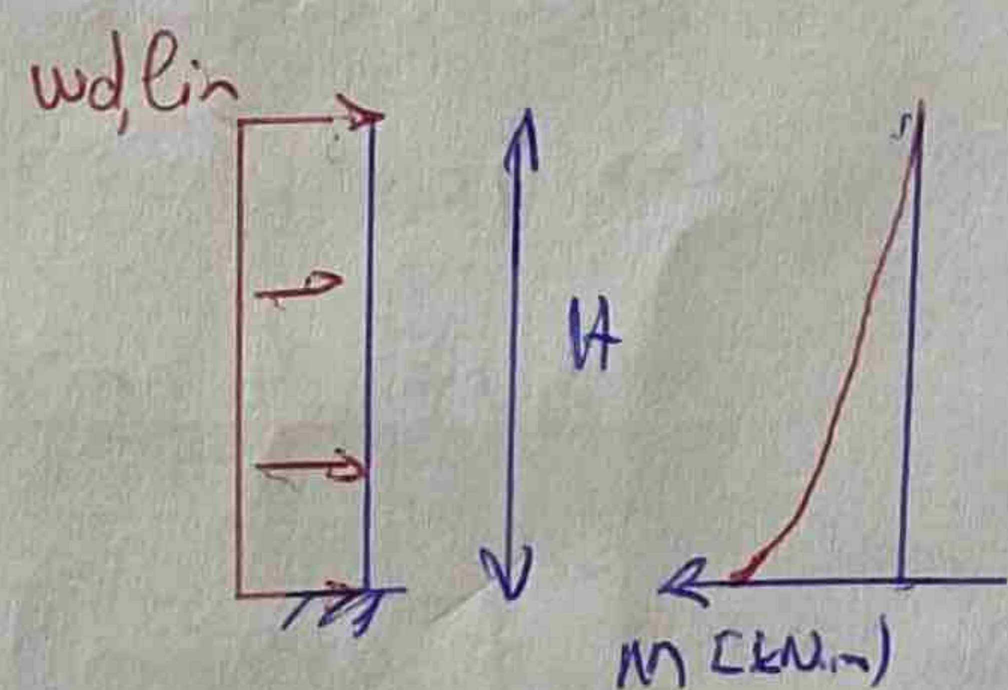
Combination C1:



The stiffening wall is only in compression. Therefore we don't need to change the dimensions of wall.

4. Calculation of stress from combination C2 et C3

C2 : Design wind load + maximum vertical load



$$M_w = \frac{1}{2} \cdot w_{d,lin} \cdot H^2$$

$$= \frac{1}{2} \cdot 28{,}47 \cdot 18{,}5^2$$

$$\simeq 4872 \text{ kNm}$$

Stress from design wind load

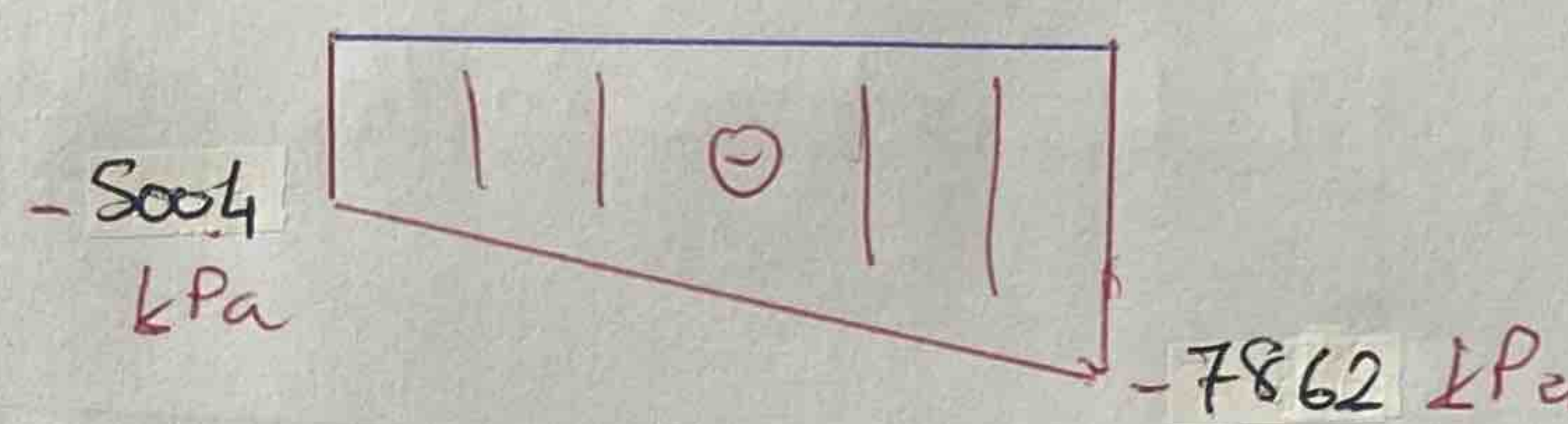
$$\sigma_W = \frac{1}{m} \cdot \frac{M_W}{W} = \frac{1}{2} \cdot \frac{4872 \times 10^3}{\frac{1}{6} \cdot 0{,}2 \cdot 7{,}15^2} \times 10^{-3} \simeq \pm 1429 \ kPa$$

Stress from maximum vertical load

$$\sigma_N = \frac{-R_{max}}{A} = \frac{-9198{,}68 \times 10^3}{0{,}2 \cdot 7{,}15} \times 10^{-3} \simeq -6433 \ kPa$$

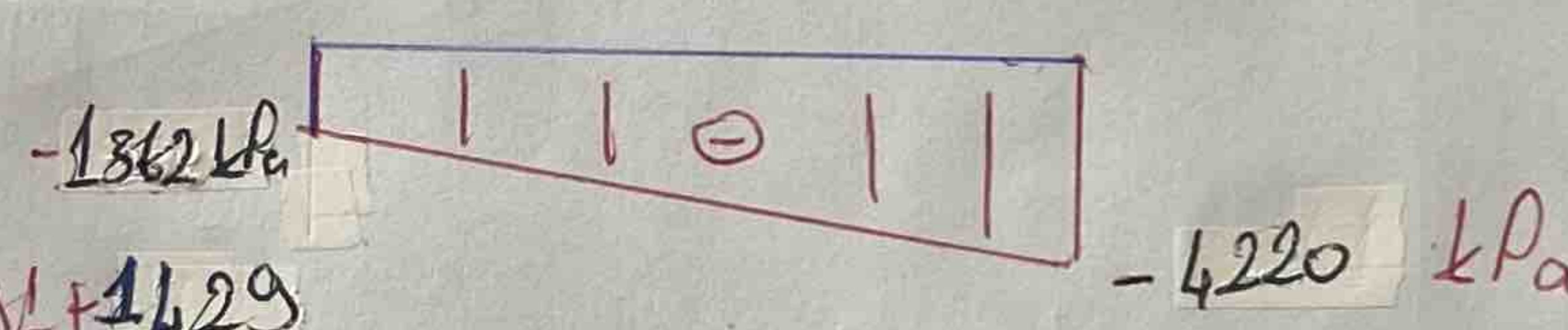
Total distribution of stress

Combination C2:



Stress from combination C3

C3: Design wind load + minimum vertical load



Any tension is occuring on our stiffening wall.

5. BASIC REINFORCEMENT

Detailling rules:

→ Vertical reinforcement: $0{,}002 a_c \leq a_{s,v} \leq 0{,}04 a_c$

$a_c = t \cdot 1m = 0{,}2 \times 1m = 0{,}2 m^2$

$0{,}002 \cdot 0{,}2 \leq a_{s,v} \leq 0{,}04 a_c$

$0{,}0004 \ m^2/m \leq a_{s,v} \leq 0{,}008 \ m^2/m$

$\Leftrightarrow 4 cm^2/m \leq a_{s,v} \ 80 \ cm^2$

$a_{s,v} = 4 \ cm^2/m$

→ Spacing of rebars: $s_v \leq \min(3t; 400 mm)$

$s_v \leq \min(3 \cdot 200 ; 400 mm)$

$s_v = 400 mm$

Horizontal reinforcement

$a_{s,h} \geq \max(0{,}25\, a_{s,v} ; 0{,}001\, a_c)$

$\geq \max(0{,}25 \cdot 0{,}0004 ; 0{,}001 \cdot 0{,}2)$

$\geq \max(0{,}0001\ m^2/m ; 0{,}0002\ m^2/m)$

$a_{s,h} = 2\ cm^2/m$

$S_h = 400\ mm$

Design reinforcement

On each side:

Vertical: $\frac{a_{s,v}}{2} = \frac{4}{2} = 2\ cm^2/m$

$\phi 10$ spacing 300mm $\Rightarrow a_s = 2{,}63\ cm^2/m > \frac{a_{s,v}}{2}$

$a_{s,v\,design} = 263 \times 2 = 526\ mm^2/m$

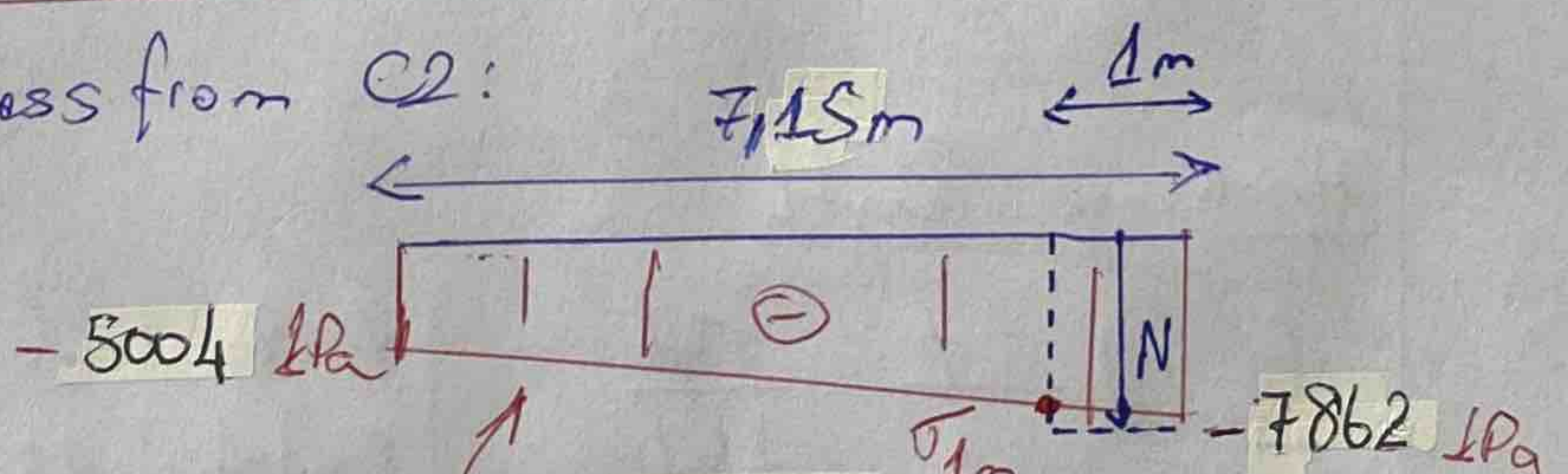
Horizontal: $\frac{a_{s,h}}{2} = \frac{2}{1} = 1\ cm^2/m$

$\phi 8$ spacing 400 mm $\Rightarrow a_s = 1{,}25\ cm^2/m > \frac{a_{s,h}}{2}$

$a_{s,h\,design} = 125 \times 2 = 250\ mm^2/m$

6. COMPRESSED REINFORCEMENT

Stress from C2:



$|q| = \frac{7862 - 5004}{7{,}15}$

$|q| = 399{,}72\ kPa$

$\sigma_{1m} = -7862 + 399{,}72 = -7462{,}28\ kPa$

$|\sigma_\phi| = \frac{7862 + 7462{,}28}{2} = 7662{,}14\ kPa$

$N = \sigma_6 \cdot t \cdot 1m = 7662{,}14 \cdot 0{,}2 \cdot 1m = 1532{,}43\ kN$

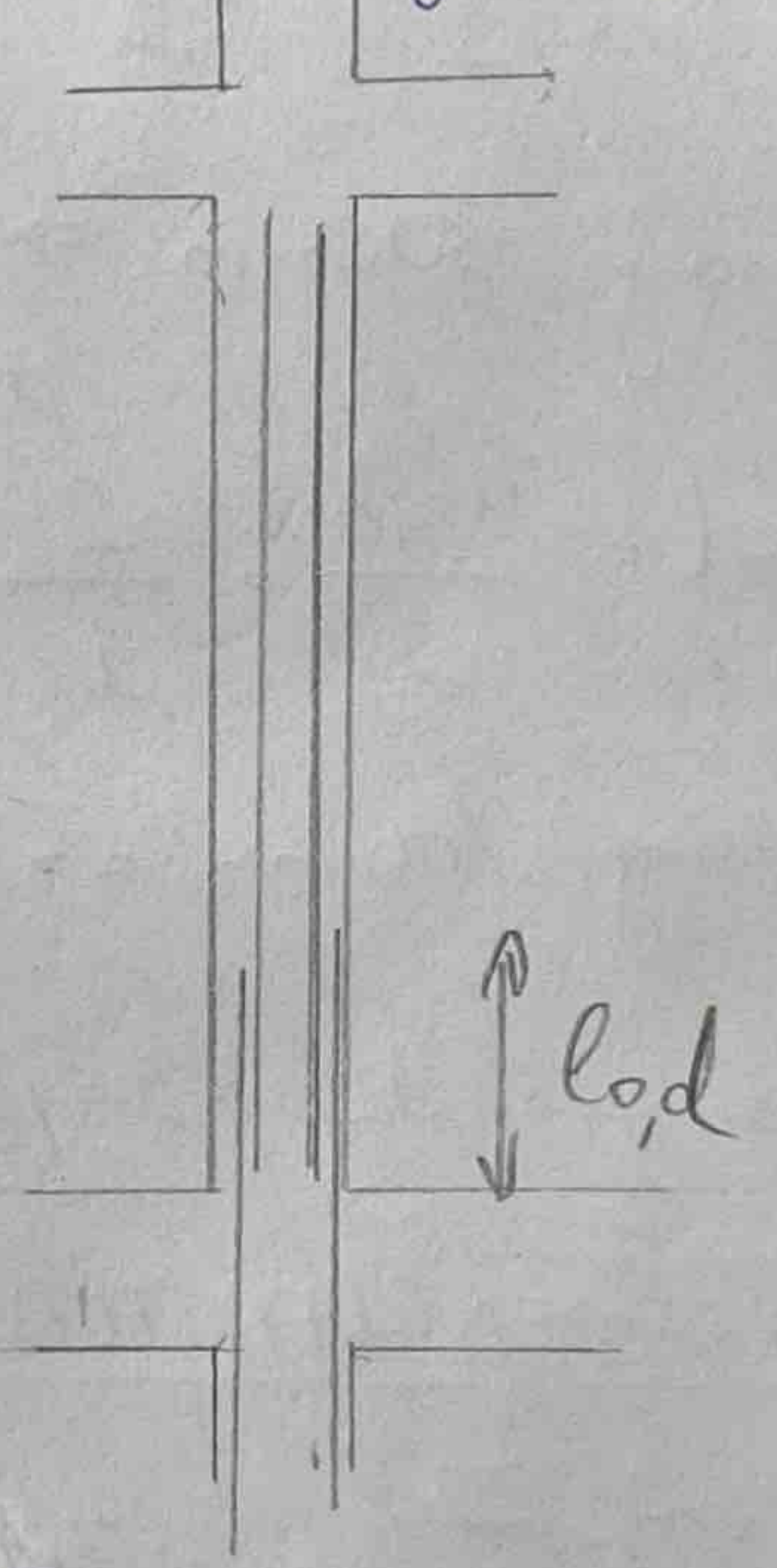
Required area of vertical reinforcement:

$$a_{s,req,v} = \frac{N - 0{,}8\, a_c \cdot f_{cd}}{\sigma_s}$$

$$= \frac{1532{,}42 \times 10^3 - 0{,}8 \cdot 92 \cdot 1 \cdot 20 \times 10^6}{400 \times 10^6} \times 10^4$$

$\approx -41{,}69\ cm^2/m < 0$, therefore we don't need to redesign reinforcement. We can use our basic reinforcement.

7. Determination of lapping length



Anchorage length

$$l_{b,rqd} = \frac{\phi}{4} \cdot \frac{\sigma_{sd}}{f_{bd}}$$

$$l_{b,rqd} = \frac{10}{4} \cdot \frac{435}{3} \approx 363\ mm$$

$$l_{0,d} = \alpha_1 \cdot \alpha_2 \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot \alpha_6 \cdot l_{b,rqd}$$

($\alpha_1 \cdot \alpha_2 \alpha_3 \cdot \alpha_4 \cdot \alpha_5 = 1$)

$$1{,}5 \cdot 363 \approx 545\ mm$$

$\phi = \phi_{vertical} = 10\ mm$

$\sigma_{sd} = f_{yd} = 435\ MPa$

For C30/37 $f_{ct,k,0,05} = 2\ MPa$

$$f_{ctd} = \frac{2}{1{,}5} \approx 1{,}33\ MPa$$

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

$$= 2{,}25 \cdot 1 \cdot 1 \cdot 1{,}33 \approx 3{,}00\ MPa$$