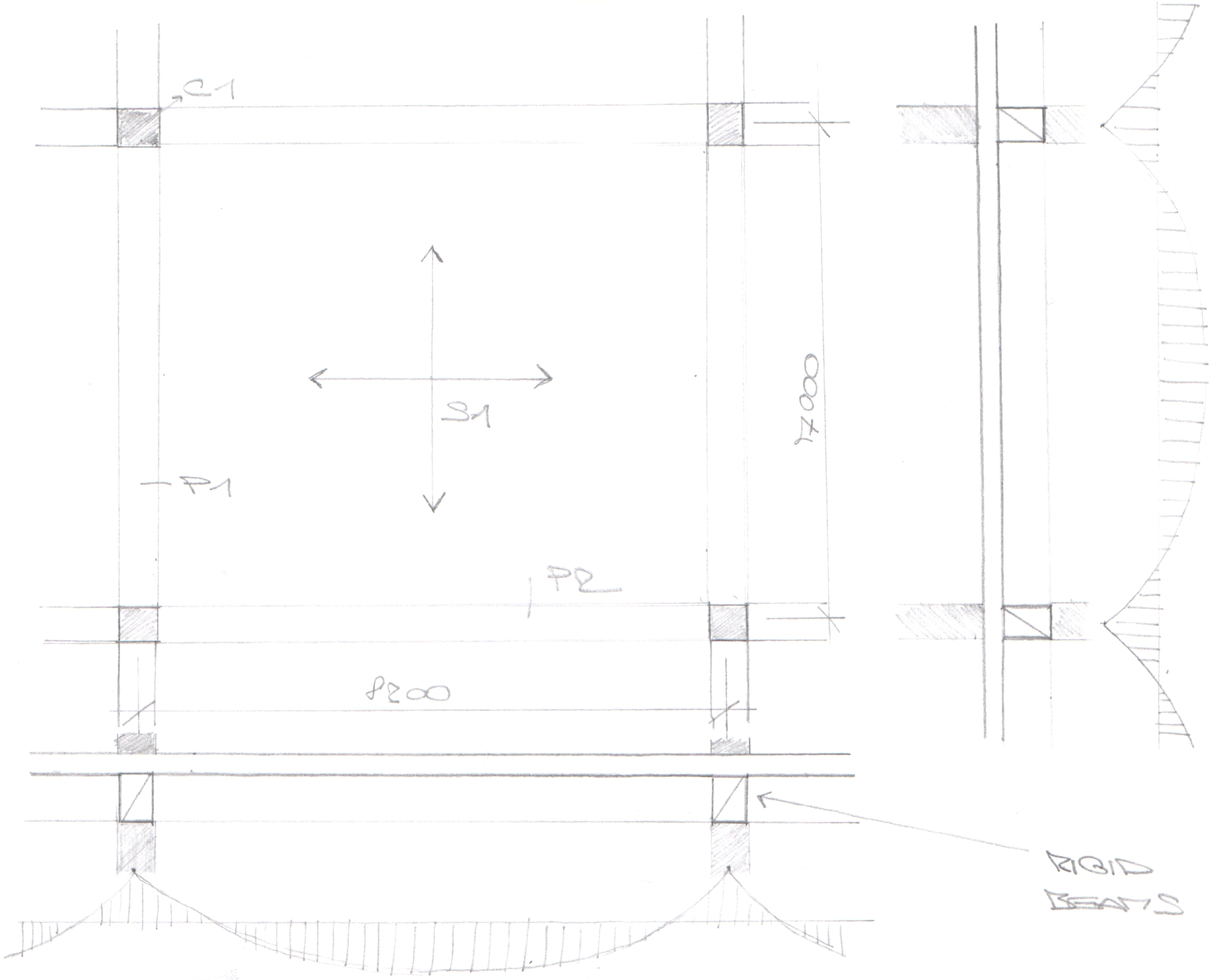
PRELIMINARY STRUCTURAL ANALYSIS:



- TWO WAY SLAB SUPPORTED ON BEAMS
- BEAMS ARE CONTINUOUS OVER THE COLUMNS
- VARIABLE LOADS ARE HIGH 7,5 kN/m²

LOADS:

- VARIABLE LOAD

  CATEGORY E1 → $q_k = 7{,}5\ kN/m^2$

  AREAS FOR STORAGE PURPOSE INCLUDING LIBRARIES AND ARCHIVES

- SNOW LOAD

  LOCATION: KUTNÁ HORA

  SNOW AREA I ; $s = 0{,}7\ kN/m^2$

  $s_k = \mu_i \cdot C_e \cdot C_t \cdot s$

  $C_e = C_t = 1{,}0$

  $\mu_i = 0{,}8$ → FLAT ROOF

$S_k = 0{,}8 \cdot 1{,}0 \cdot 1{,}0 \cdot 0{,}7 = 0{,}56\ kN/m^2$

- WIND LOAD

WIND AREA II , $v_b = 25\ m/s$

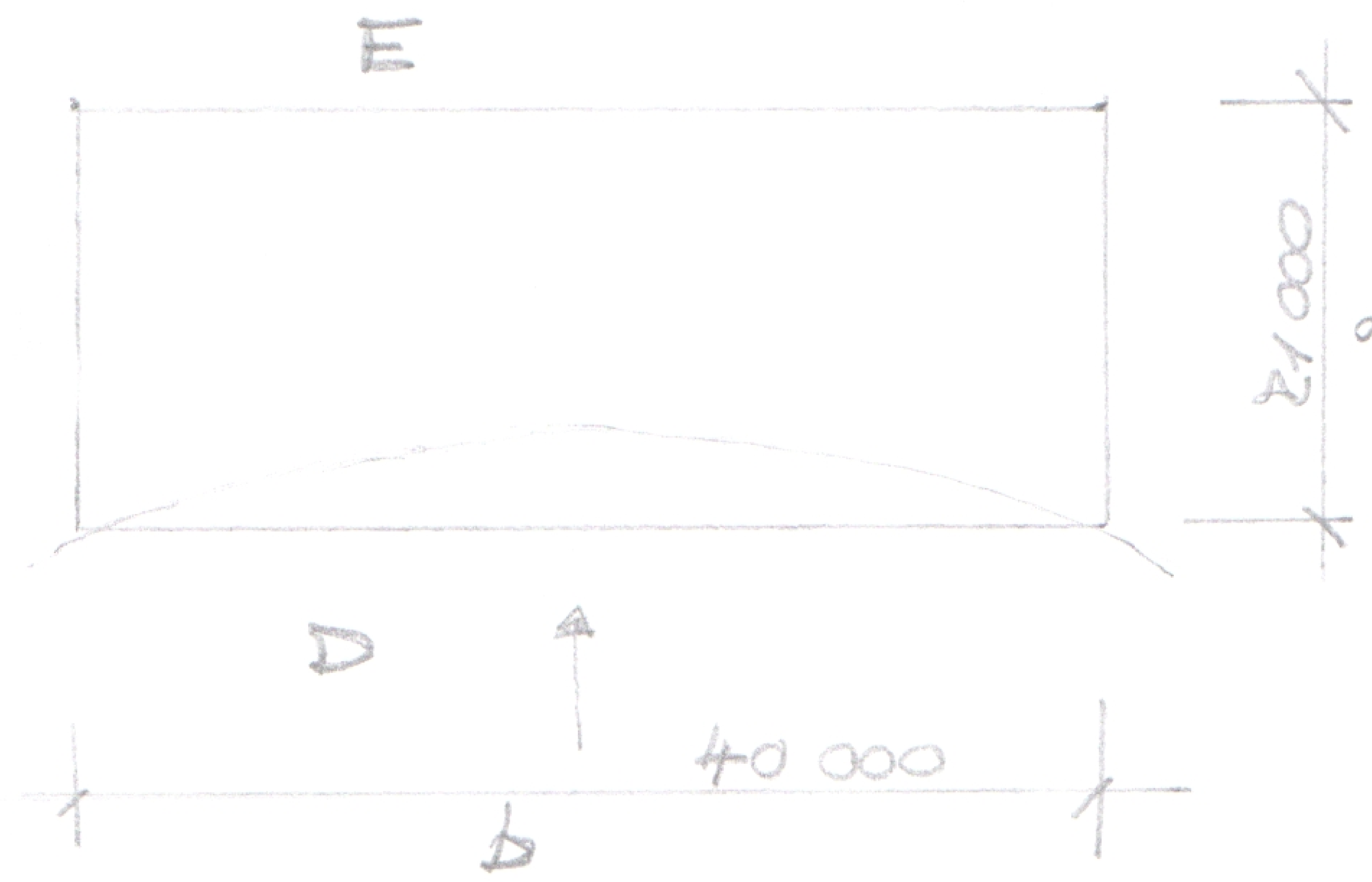
TERRAIN CATEGORY IV DOWNTOWN

HEIGHT OF THE BUILDING : $z = 12{,}9\ m$

$$q_b = \frac{1}{2} \cdot \rho_v \cdot v_b^2 = \frac{1}{2} \cdot 1{,}25 \cdot 25^2 = 390{,}63\ N/m^2$$

$\rho_v = 1{,}25\ kg/m^3$ $= 0{,}39\ kN/m^2$

$v_b = 22{,}5\ m/s$



$z = h = 12{,}9\ m$

$$\frac{h}{d} = \frac{12{,}9}{21} = 0{,}61 < 1{,}0$$

$C_{pe} = 0{,}75 \rightarrow D$

$C_{pe} = +0{,}48 \rightarrow E$

$C_{pe} = 1{,}23\ [-]$

$w_k = q_b \cdot C_e(z) \cdot C_{pe} =$

$w_k = 0{,}39 \cdot 1{,}3 \cdot 1{,}23 = 0{,}62\ kN/m^2$

- DEAD LOAD

a) TYPICAL FLOOR

NAME OF LAYER	MASS (kg/m^3)	t [m]	g_k [kN/m^2]	γ_F	g_d [kN/m^2]
LEVELING FLOOR	2100	0,010	0,21	1,35	
CEMENT FLOOR LAY.	2100	0,080	1,68	—"—	
POLYSTYREN	35	0,060	0,021	—"—	
COLOR. SLABS	2500	0,200	5	—"—	
CEILING PLANF	—	—	0,2	—"—	
			7,11	—"—	9,6

b) ROOF COMPOSITION

NAME OF LAYER	MASS [kg/m^3]	t [m]	g_k [kN/m^2]	γ_f	g_d [kN/m^2]
CONCR. PAVEMENT	2300	0,030	0,69	1,35	
EXTR. POLYSTYREN	35	0,250	0,088	—"—	
BIT. SHEET	—	—	0,052	—"—	
BIT. SHEET	—	—	0,052	—"—	
SLOPE CONCRETE	2300	0,080	1,84	—"—	
CONCR. SLAB	2500	0,200	5	—"—	
CEILING KNAUF	—	—	0,2	—"—	
			7,922	—"—	10,69

· FINAL DESIGN LOADS

a) TYPICAL FLOOR

$g_k = 7,5 \ kN/m^2$

$q_d = 7,5 \cdot 1,5 = 11,25 \ kN/m^2$

$g_d = 9,6 \ kN/m^2$

$f_d = q_d + g_d = 11,25 + 9,6 = \underline{20,85 \ kN/m^2}$

b) ROOF STRUCTURE

$S_k = 0,56 \ kN/m^2$

$S_d = 0,56 \cdot 1,5 = 0,84 \ kN/m^2$

$g_d = 10,69 \ kN/m^2$

$f_d = S_d + g_d = 0,84 + 10,69 = \underline{11,53 \ kN/m^2}$

SLAB S1

TWO WAY SLAB SUPPORTED ON BEAMS

WAFFLE SLAB

CONTINUOUS END

· EMPIRICAL ESTIMATION

$$h_s = \frac{L}{40} = \frac{8200}{40} = 205 \ mm$$

$$h_s = 1,2 \cdot (L_1 + L_2) / 105 = 175 \ mm$$

$h_s = 200 \ mm$

$$\frac{\text{LONGER SPAN}}{\text{SHORTER SPAN}} < 1,5$$

$$\frac{8200}{7000} = 1,2 < 1,5 \checkmark$$

- COVER DEPTH:

$C = C_{MIN} + \Delta C_{DEV}$

$C_{MIN} = 10\ MM$

$15\ MM \rightarrow S4\ ;\ XC1$

$10\ MM$

$\Delta C_{DEV} = 10\ MM$

$C = 15 + 10 = 25\ MM$

- EFFECTIVE DEPTH

$$d = h_s - c - \frac{\phi}{2} = 200 - 25 - \frac{10}{2} = 170\ MM$$

- SPAN/DEPTH RATIO

DEFLECTION CONTROL

$$\lambda = \frac{l}{d} \leq \lambda_{lim} = K_{C1} \cdot K_{C2} \cdot K_{C3} \cdot l_{d\,TAB}$$

$$\lambda = \frac{8200}{170} = 48,3$$

$$\lambda_{lim} = 1,0 \cdot 1,0 \cdot 1,2 \cdot 25,5 = 30,6$$

$$\lambda \leq \lambda_{LIM}$$

$$48,3 > 30,6 \quad \times$$

INCREASE $h_s = 300\ MM$

$$d = 300 - 25 - \frac{10}{2} = 270\ MM$$

$$\lambda = \frac{8200}{270} = 30,4$$

$$30,4 < 30,6 \checkmark$$

BEAM P1

- EMPIRICAL ESTIMATION

$$h_B = \frac{l}{12} - \frac{l}{8} = \frac{7000}{12} - \frac{7000}{8} = 583 - 875\ MM$$

$h_B = 600$ mm

$b = (0,3 - 0,5)\, h_B = (0,3 - 0,5) \cdot 600 = 180 - 300$ mm

$b = 300$ mm

- CHECK OF THE BEAM RIGIDITY

$$h_B \geq 2,5\, h_S$$

$$600 \geq 2,5 \cdot 300$$

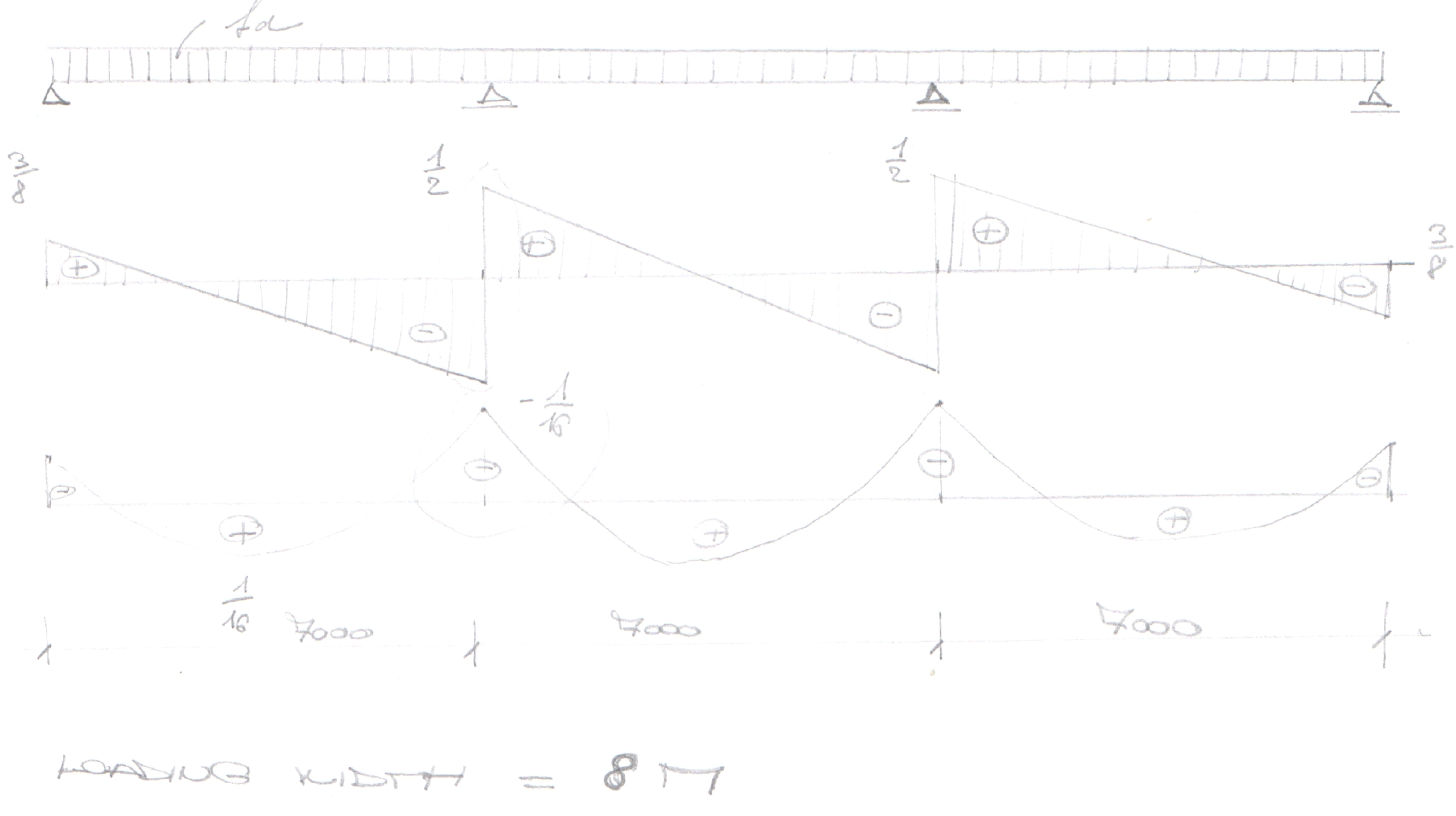
$$600 \leq 750 \text{ mm} \times$$

BEAM HAS TO BE INCREASED

$h_B = 750$ mm

$$750 = 750 \text{ mm} \checkmark$$

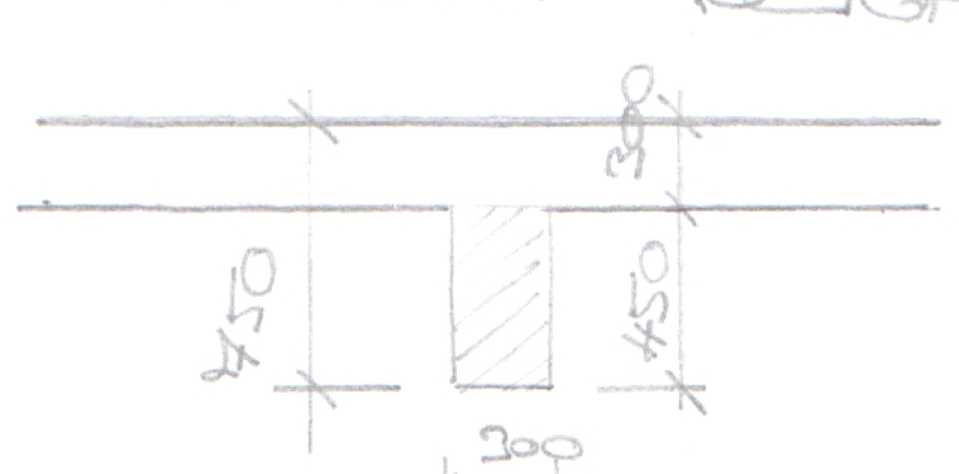
PRELIMINARY CHECK OF BEAM



LOADING WIDTH = 8 m

$f_d = 20,85 \cdot 8 = 166,8$ kN/m'

BEAM SELF WEIGHT



$f_d = 0,45 \cdot 0,3 \cdot 1 \cdot 25 \cdot 1,35$

$f_d = 4,56$ kN/m'

$f_d = 166,8 + 4,56 = 171,36$ kN/m'

$V_{Ed,max} = 0,5 \cdot f_d \cdot l = 0,5 \cdot 171,36 \cdot 7,0 =$

$= 599,8 \ kN$

$M_{Ed,max} = \frac{1}{16} \cdot f_d \cdot l^2 = \frac{1}{16} \cdot 171,36 \cdot 7,0^2 = 524,8 \ kN.m$

- PRELIMINARY CHECK OF BENDING

$\mu = \frac{M_{Ed,max}}{b_B \cdot d_B^2 \cdot f_{cd}}$ C 20/25, ϕ 20 mm

$d_B = 750 - 25 - \frac{20}{2} = 715 \ mm$

$f_{cd} = \frac{f_{ck}}{1,5} = \frac{20}{1,5} = 13,3 \ MPa$

$\mu = \frac{524,8 \cdot 10^6}{300 \cdot 715^2 \cdot 13,3} = 0,25 \rightarrow \xi = 0,366 \ [-]$

$0,15 < 0,366 < 0,4$ ✓

- PRELIMINARY CHECK OF REINFORCEMENT RATIO

$\rho_{s,reqd} = \frac{A_{s,reqd}}{A_c} = \frac{\frac{M_{Ed,max}}{z \, d_B \cdot f_{yd}}}{b_B \cdot d_B} = \frac{\frac{524,8 \ 10^6}{0,854 \cdot 715 \cdot 435}}{300 \cdot 715}$

$\rho_{s,reqd} = 0,0092 < 0,04$ ✓

- PRELIMINARY CHECK OF LOAD B. CAPACITY IN SHEAR

$V_{Rd,max} = \nu \cdot f_{cd} \cdot b_B \cdot z \cdot d_B \cdot \frac{\cot \varphi}{1 + \cot^2 \varphi} \geq V_{Ed,max}$

$V_{Rd,max} = 0,6 \cdot \left(1 - \frac{20}{250}\right) \cdot 13,3 \cdot 300 \cdot 0,854 \cdot 715 \cdot \frac{1,5}{1 + 1,5^2} =$

$V_{Rd,max} = 620,7 > 524,8 \ kN$ ✓

- SPAN/DEPTH RATIO

$\lambda = \frac{l}{d} = \frac{7000}{715} = 9,8$

$$\lambda_{LIM} = 1{,}0 \cdot 1{,}0 \cdot 1{,}2 \cdot 16{,}9 = 20{,}28$$

$$20{,}28 > 9{,}8 \checkmark$$

BEAM P2

EMPIRICAL ESTIMATION

$$h_B = \frac{l}{12} - \frac{l}{8} = \frac{8200}{12} - \frac{8200}{8} = 683 - 1025\ MM$$

$$h_B = 750\ MM$$

$$b = (0{,}3 - 0{,}5) \cdot h_B = (0{,}3 - 0{,}5) \cdot 750 = 225 - 375\ MM$$

$$b = 300\ MM$$

PRELIMINARY CHECK OF THE BEAM

LOADING WIDTH $b_{ES} = 7\ M$

$$f_d = 20{,}85 \cdot 7 = 145{,}95\ kN/M'$$

SELF WEIGHT $f_d = 0{,}45 \cdot 0{,}3 \cdot 1 \cdot 25 \cdot 1{,}35 = 4{,}56\ kN/M'$

$$f_d = 145{,}95 + 4{,}56 = 150{,}51\ kN/M'$$

$$V_{ED,MAX} = 0{,}5 \cdot f_d \cdot l = 0{,}5 \cdot 150{,}51 \cdot 8{,}2 = 617\ kN$$

$$M_{ED,MAX} = \frac{1}{16} \cdot f_d \cdot l^2 = \frac{1}{16} \cdot 150{,}51 \cdot 8{,}2^2 = 632{,}5\ kN.M$$

PRELIMINARY CHECK OF BENDING

$$\mu = \frac{M_{ED,MAX}}{b_B \cdot d_B^2 \cdot f_{cd}} = \frac{632{,}5 \cdot 10^6}{300 \cdot 715^2 \cdot 13{,}3} = 0{,}31 \rightarrow$$

$$\xi = 0{,}479 > 0{,}4\ [-]$$

INCREASE $h_B = 850\ MM$

$$d_B = 850 - 25 - \frac{20}{2} = 815\ MM$$

$$\mu = \frac{M_{ED,MAX}}{b_B \cdot d_B^2 \cdot f_{cd}} = \frac{632{,}5 \cdot 10^6}{300 \cdot 815^2 \cdot 13{,}3} = 0{,}24 \rightarrow$$

$$\xi = 0,343 < 0,4 \checkmark$$

PRELIMINARY CHECK OF REINFORCEMENT RATIO

$$\rho_{s,rqd} = \frac{A_{s,rqd}}{A_c} = \frac{\frac{M_{ED,MAX}}{z \cdot d_B \, f_{yd}}}{b_B \cdot d_B} = \frac{\frac{632,5 \cdot 10^6}{0,861 \cdot 815 \cdot 435}}{300 \cdot 815}$$

$$\rho_{s,rqd} = 0,0085 < 0,04 \checkmark$$

PRELIMINARY CHECK OF LOAD B. CAPACITY IN SHEAR

$$V_{RD,MAX} = \nu \cdot f_{cd} \cdot b_B \cdot z \cdot d_B \cdot \frac{\cot\varphi}{1+\cot^2\varphi} \geq V_{ED,MAX}$$

$$V_{RD,MAX} = 0,6 \cdot \left(1 - \frac{20}{250}\right) \cdot 13,3 \cdot 300 \cdot 0,861 \cdot 815 \cdot \frac{1,5}{1+1,5^2}$$

$$V_{RD,MAX} = 713,3 > 617 \text{ kN} \checkmark$$

- SPAN / DEPTH RATIO

$$\lambda = \frac{l}{d} = \frac{8200}{815} = 10,06$$

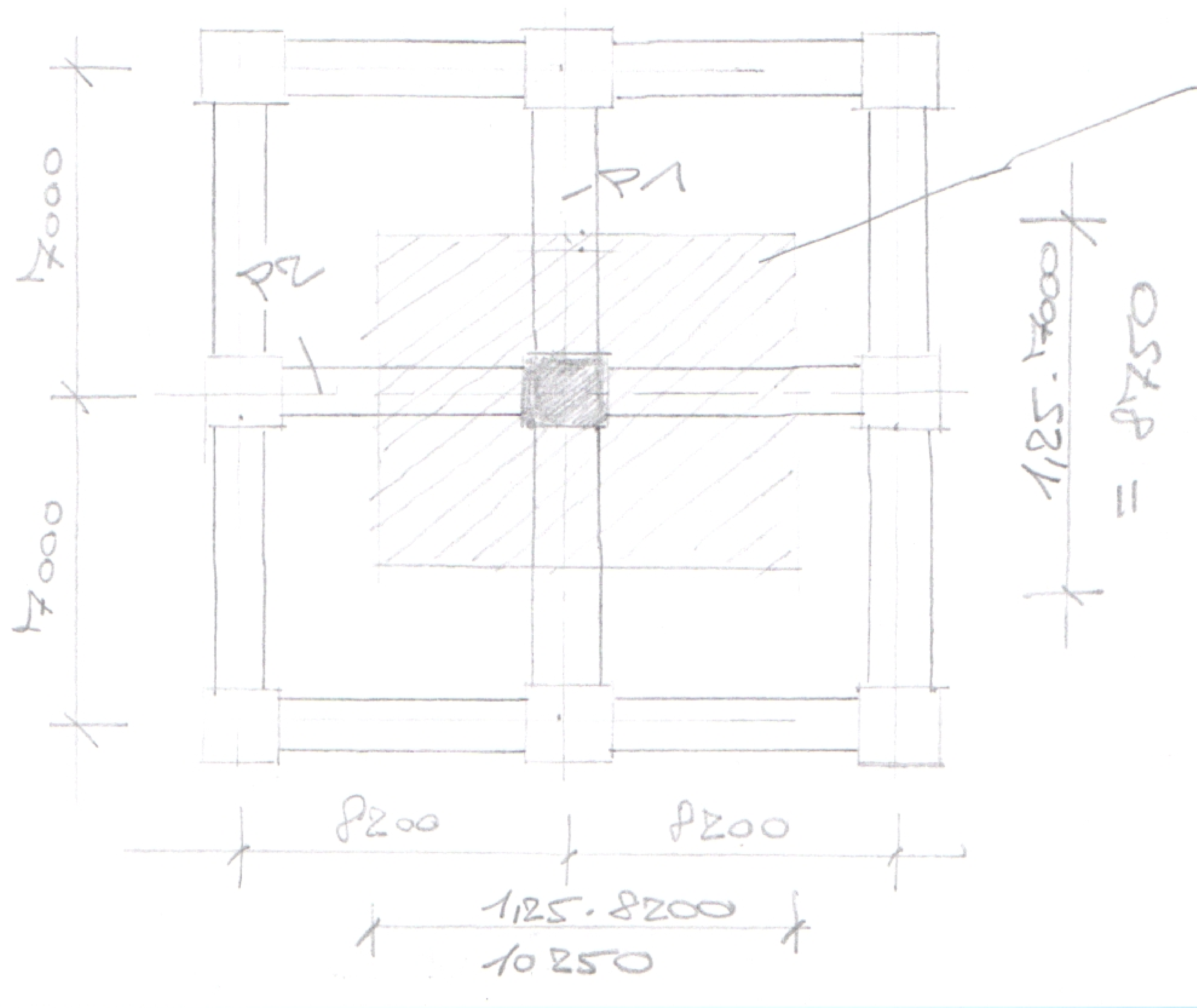
$$\lambda_{LIM} = 1,0 \cdot 1,0 \cdot 1,2 \cdot 16,9 = 20,28$$

$$20,28 > 10,06 \checkmark$$

COLUMN C1

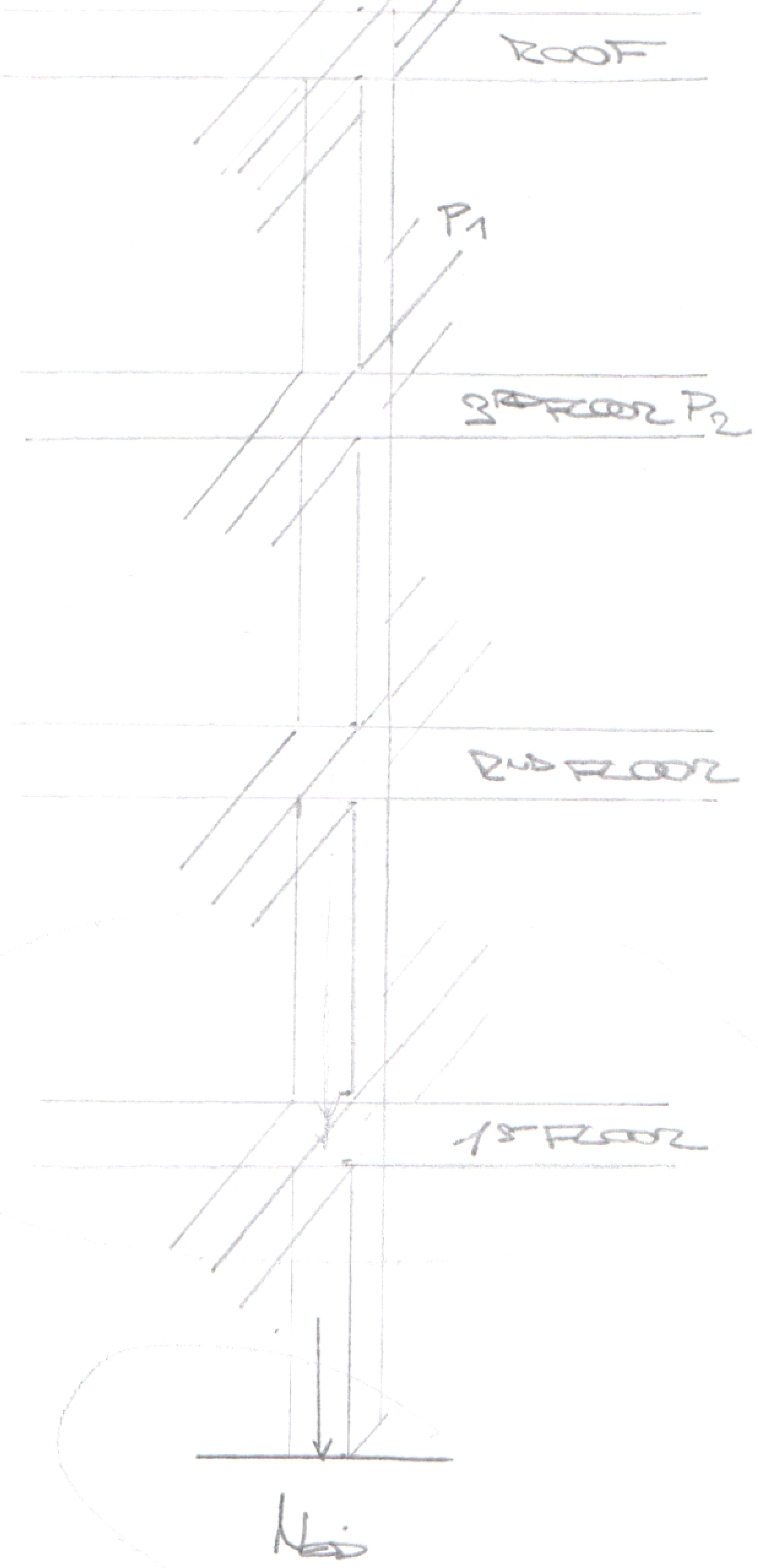
DESIGN LOAD IN THE FOOT OF THE COLUMN

NEXT PAGE



$$A = 10,25 \times 8,75$$

$$A = 89,69 \text{ m}^2$$



LOAD FROM THE SLAB:

3 x TYPICAL FLOOR $3 \times 89{,}69\,m^2 \times 20{,}85\,kN/m^2 = 5610\,kN$

1 x ROOF $1 \times 89{,}69\,m^2 \times 11{,}53\,kN/m^2 = 1034\,kN$

$6644\,kN$

LOAD FROM THE BEAM:

$P1: 0{,}45 \cdot 0{,}3 \cdot 8{,}750 \cdot 25 \cdot 1{,}35 = 39{,}9\,kN$

$P2: 0{,}55 \cdot 0{,}3 \cdot 10{,}250 \cdot 25 \cdot 1{,}35 = 57{,}08\,kN$

4 x FLOORS $\rightarrow 4 \times (39{,}9 + 57{,}08) = 387{,}92\,kN$

SELF WEIGHT OF THE COLUMN:

$C1: 0{,}5 \cdot 0{,}5 \cdot 3{,}5 \cdot 25 \cdot 1{,}35 = 29{,}53\,kN$

$4 \times 29{,}53 = 118{,}13\,kN$

$N_{ED} = 6644 + 387{,}92 + 118{,}13 = 7150\,kN$

$N_{ED} = 0{,}8 \cdot A_c \cdot f_{cd} + A_s \cdot S_s$

$A_s = 0{,}02\,A_c$ $\quad f_{cd} = \frac{f_{ck}}{1{,}5} = \frac{25}{1{,}5} = 16{,}67\,MPa$

$S_s = 400\,MPa$

$7150 = 0{,}8 \cdot A_c \cdot 16{,}67 \cdot 10^3 + 0{,}02 \cdot A_c \cdot 400\,000$

$7150 = A_c \cdot 21336$

$A_c = 0{,}335\,m^2 \rightarrow$ $0{,}57 \times 0{,}57\,m$

COLUMN **600 x 600 MM**

FLAT SLAB PRELIMINARY DESIGN

$$h_s = \frac{l_{max}}{33} = \frac{8800}{33} \doteq 250 \text{ MM}$$

$$d = h_s - c - \frac{\phi}{2} = 250 - 25 - \frac{10}{2} = 220 \text{ MM}$$

SPAN DEPTH RATIO:

$$\lambda = \frac{l}{d} \leq \lambda_{LIM} = k_{c1} \cdot k_{c2} \cdot k_{c3} \cdot \lambda_{d,TAB}$$

$$\lambda = \frac{8200}{220} = 37,3 < 1,0 \cdot 1,0 \cdot 1,2 \cdot 24,6 = 29,52$$

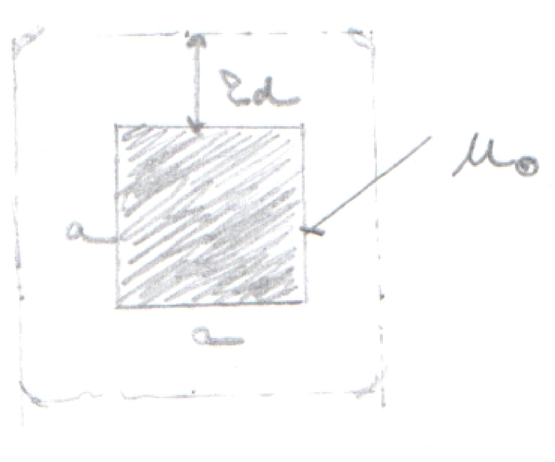
INCREASE DEPTH OF THE SLAB

$$h_s = 300 \text{ MM}$$

$$d = 300 - 25 - \frac{10}{2} = 270 \text{ MM}$$

$$\lambda = \frac{8200}{270} \doteq 30 = 30 \checkmark$$

PRELIMINARY CHECK OF PUNCHING



$$u_0 = 4 \cdot a$$

$$a = 600 \text{ MM}$$

$$u_0 = 4 \cdot 600 = 2400 \text{ MM}$$

$$u_1 = 4 \cdot a + 2\pi \cdot 2d$$

$$u_1 = 4 \cdot 600 + 2\pi \cdot 2 \cdot 270 = 5792 \text{ MM}$$

STRESS IN PERIMETER u_0

$$v_{Ed,0} = \frac{\beta \cdot V_{Ed}}{u_0 d} \leq v_{Rd,max} = 0,4 \cdot \nu \cdot f_{cd}$$

V_{Ed} = NORMAL FORCE IN THE COLUMN FROM ONE FLOOR (1st FLOOR, LOAD FROM THE SLAB + BEAMS)

$$V_{Ed} = 1870 + 39,3 + 57,08 = 1967 \text{ kN}$$

$$f_{cd} = \frac{f_{ck}}{\gamma_M} = \frac{30}{1,5} = 20 \text{ MPa}$$

$$\nu = 0,6 \cdot \left(1 - \frac{f_{ck}}{250}\right) = 0,6 \cdot \left(1 - \frac{30}{250}\right) =$$

$$\nu = 0,528$$

$$v_{Rdmax} = 0,4 \cdot 0,528 \cdot 20 = 4,224 \text{ MPa}$$

$$v_{Ed,0} = \frac{1,15 \cdot 1967 \cdot 10^3}{2400 \cdot 270} = 3,49 \text{ MPa}$$

$$\underline{3,49 < 4,224 \text{ MPa}} \ \checkmark$$

STRESS IN PERIMETER u_1

$$v_{Ed1} = \frac{\beta \cdot V_{Ed}}{u_1 \cdot d} \leq k_{max} \cdot v_{Rd,c} = k_{max} \cdot C_{Rd,c} \cdot k \cdot$$

$$\sqrt[3]{(100 \cdot \rho_1 \cdot f_{ck})}$$

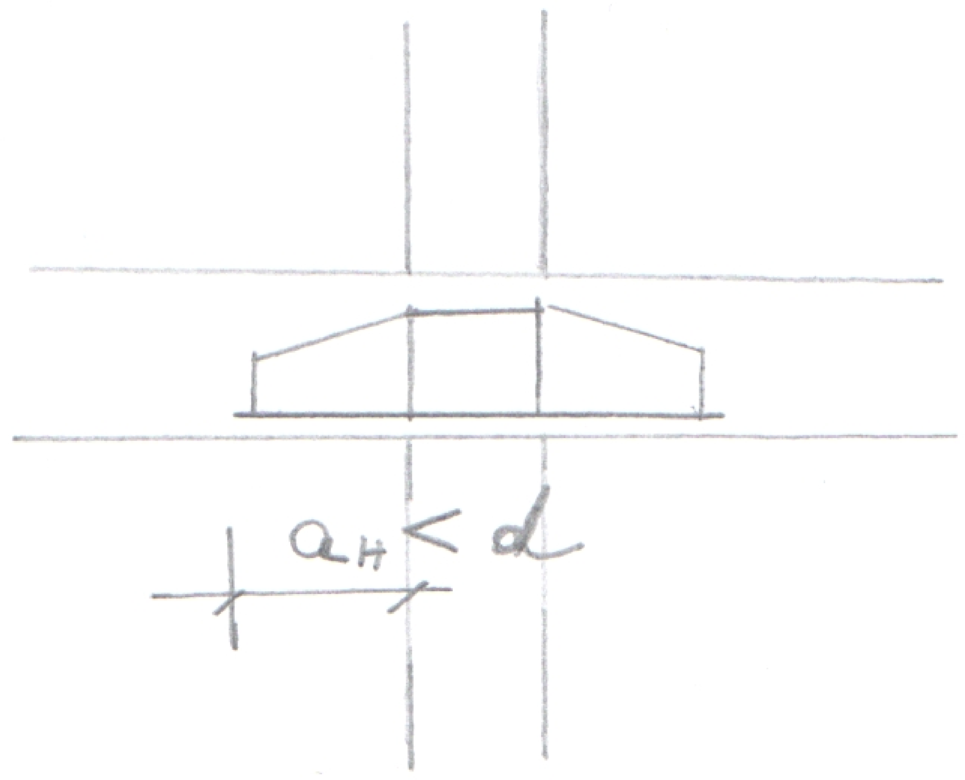
$$v_{Ed1} = \frac{1,15 \cdot 1967 \cdot 10^3}{57792 \cdot 270} = 1,45 \text{ MPa}$$

$$1,29 \cdot 0,12 \cdot \left(1 + \overbrace{\sqrt{\frac{200}{270}}}^{\to 1,86}\right) \cdot \overbrace{\sqrt[3]{(100 \cdot 0,005 \cdot 30)}}^{\to 2,46} = 0,708$$

$$\underline{1,45 > 0,708 \text{ MPa}} \ \times$$

NOT CHECKED → REINFORCEMENT IS NOT ANCHORED

DESIGN COLUMNS WITH CAPS: → STEEL FLANGED COLLARS



$$u_0 = 4 \cdot a + 8 \cdot a_h$$

$$a_h = 270 \text{ MM}$$

$$u_1 = 4 \cdot a + 8 \cdot a_h + 2\pi \cdot 2d$$

$$u_1 = 4 \cdot 600 + 8 \cdot 270 + 2\pi \cdot 2 \cdot 270$$

$$u_1 \doteq 7953 \text{ MM}$$

INCREASE DEPTH OF THE SLAB

$h_s = 330$ MM

$d = 330 - 25 - \frac{10}{2} = 300$ MM

$v_{Ed1} = \frac{1{,}15 \cdot 1967 \cdot 10^3}{7953 \cdot 300} = 0{,}94$ MPa

$1{,}31 \cdot 0{,}12 \cdot 1{,}81 \cdot 2{,}46 = 0{,}7$ MPa

$0{,}94 > 0{,}7$ MPa ✗

NOT CHECKED

$h_s = 350$ MM

$d = 350 - 25 - \frac{10}{2} = 320$ MM

$u_1 = 4 \cdot 600 + 8 \cdot 320 + 2\pi \cdot 2 \cdot 320 = 8981$ MM

$v_{Ed1} = \frac{1{,}15 \cdot 1967 \cdot 10^3}{8981 \cdot 320} = 0{,}78$ MPa

$1{,}322 \cdot 0{,}12 \cdot 1{,}8 \cdot 2{,}46 = 0{,}7$ MPa

$0{,}78 > 0{,}7$ MPa ✗

$h_s = 380$ MM

$d = 380 - 25 - \frac{10}{2} = 350$ MM

$u_1 = 4 \cdot 600 + 8 \cdot 350 + 2\pi \cdot 2 \cdot 350 = 9599$ MM

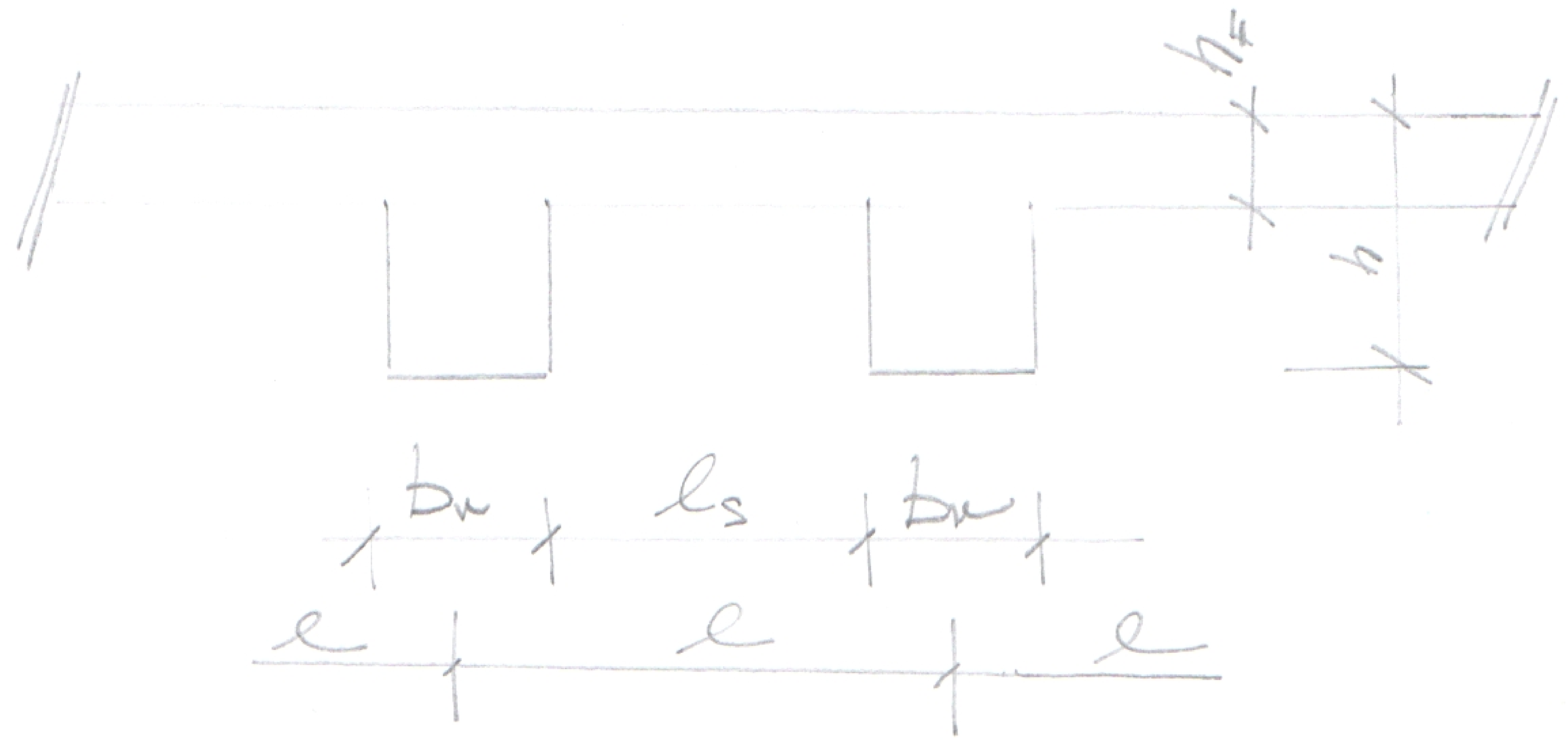
$v_{Ed1} = \frac{1{,}15 \cdot 1967 \cdot 10^3}{9599 \cdot 350} = 0{,}67$ MPa

$1{,}34 \cdot 0{,}12 \cdot 1{,}8 \cdot 2{,}46 = 0{,}7$ MPa

$0{,}67 < 0{,}7$ MPa ✓

WAFFLE SLAB CALCULATION:

RIBBED SLABS COULD BE ANALYSED AS SOLID SLABS, IF RIGID ENOUGH



$h = 380$ MM

$l \leq 2.h = 2.380 = 760$ MM

$l = 700$ MM

$b_w = 200$ MM

$l_s = 700 - 200 = 500$ MM

$h_f \geq 1/10 . l_s = \frac{1}{10} . 500 = 50$ MM

$h_f = 100$ MM

SECTION OF THE WAFFLE SLAB