Assignment 6

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Scheme – E

Member – P2

$a = 5{,}4\,m$

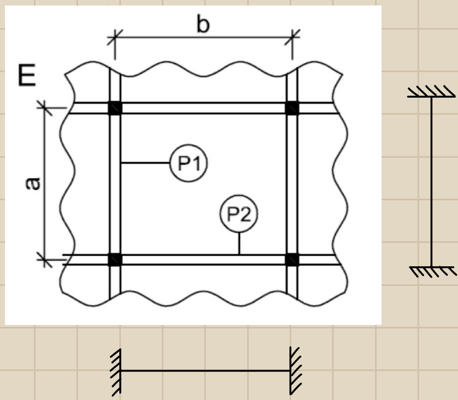
$b = 6{,}7\,m$

$h_s = 190\,mm$

C 25/30

$(g-g_0)_{floor,k} = 1{,}4\,kN/m^2$

$q_{floor,k} = 4{,}9\,kN/m^2$



1. Supports

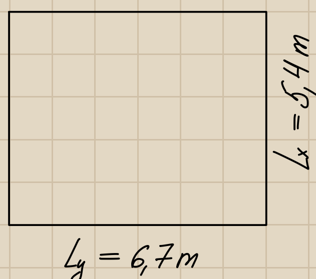
Inner beams => fixed supports

2. Loading of the slab

Load type	k-value [kN/m²]	γ	design value [kN/m²]
Self-weight	$25\,kN/m^3 \cdot 0{,}19\,m =$ 4,75	1,35	6,41
Dead load	1,4	1,35	1,89
Live load	4,9	1,5	7,35
Total	11,05		15,65

3. Bending moments – Strip Method (elastic)

$$w_x\left(\frac{l_x}{2}\right) = w_y\left(\frac{l_y}{2}\right)$$



$$w = k \cdot \frac{fl^4}{EI}$$

$$k_x \cdot \frac{f_x \cdot l_x^4}{\cancel{EI}} = k_y \cdot \frac{f_y \cdot l_y^4}{\cancel{EI}} \Rightarrow f_y = f_x \cdot \frac{k_x \cdot l_x^4}{k_y \cdot l_y^4}$$

For both fixed supports: $k_x = k_y = \frac{1}{384}$

$$\Rightarrow f_y = f_x \cdot \frac{l_x^4}{l_y^4} \Rightarrow f_y = 0{,}422\, f_x$$

$$f = f_x + f_y$$

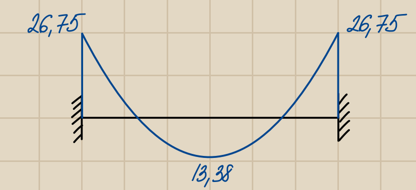
$$f = f_x + 0{,}422\, f_x$$

$$f_d = 1{,}422\, f_{d,x}$$

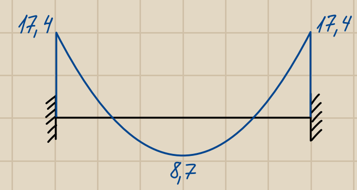
$$1{,}422\, f_{d,x} = 15{,}65 \Rightarrow f_{d,x} = 11{,}01\ kN/m^2$$

$$f_{d,y} = 0{,}422 \cdot 11{,}01 = 4{,}65\ kN/m^2$$

X direction



Y direction



$$\frac{1}{24} \cdot 11{,}01 \cdot 5{,}4^2 = 13{,}38\ kNm$$

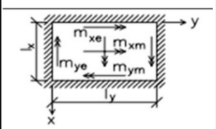
$$\frac{1}{12} \cdot 11{,}01 \cdot 5{,}4^2 = 26{,}75\ kNm$$

$$\frac{1}{24} \cdot 4{,}65 \cdot 6{,}7^2 = 8{,}70\ kNm$$

$$\frac{1}{12} \cdot 4{,}65 \cdot 6{,}7^2 = 17{,}40\ kNm$$

4. Bending moments – Yield Line Theory (plastic)

Slab is supported by 4 inner beams => choose this scheme

Supports		ly/lx										
		1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
	βxe	-0.032	-0.038	-0.043	-0.047	-0.051	-0.053	-0.057	-0.058	-0.060	-0.062	-0.064
	βxm	0.024	0.028	0.032	0.035	0.038	0.040	0.042	0.044	0.045	0.047	0.048
	βye	-0.032										
	βym	0.024										

Ratio of spans: $\frac{l_y}{l_x} = \frac{6{,}7}{5{,}4} = 1{,}24$

Interpolation:

$$\frac{4}{0{,}1}$$

$$\beta_{xe}(1{,}2) = -0{,}043$$

$$\beta_{xe}(1{,}3) = -0{,}047$$

$-0{,}047-(-0{,}043)=-0{,}004$

$-0{,}004\cdot 0{,}4=-0{,}0016$

$\beta_{xe}(1{,}24)=-0{,}043-0{,}0016=-0{,}0446$

$\beta_{xm}(1{,}2)=0{,}032$

$\beta_{xm}(1{,}3)=0{,}035$

$0{,}035-0{,}032=0{,}003$

$0{,}003\cdot 0{,}4=0{,}0012$

$\beta_{xm}(1{,}24)=0{,}0332$

$m_0=f_d\cdot l_x^2=15{,}65\cdot 5{,}4^2=456{,}35\ kN$

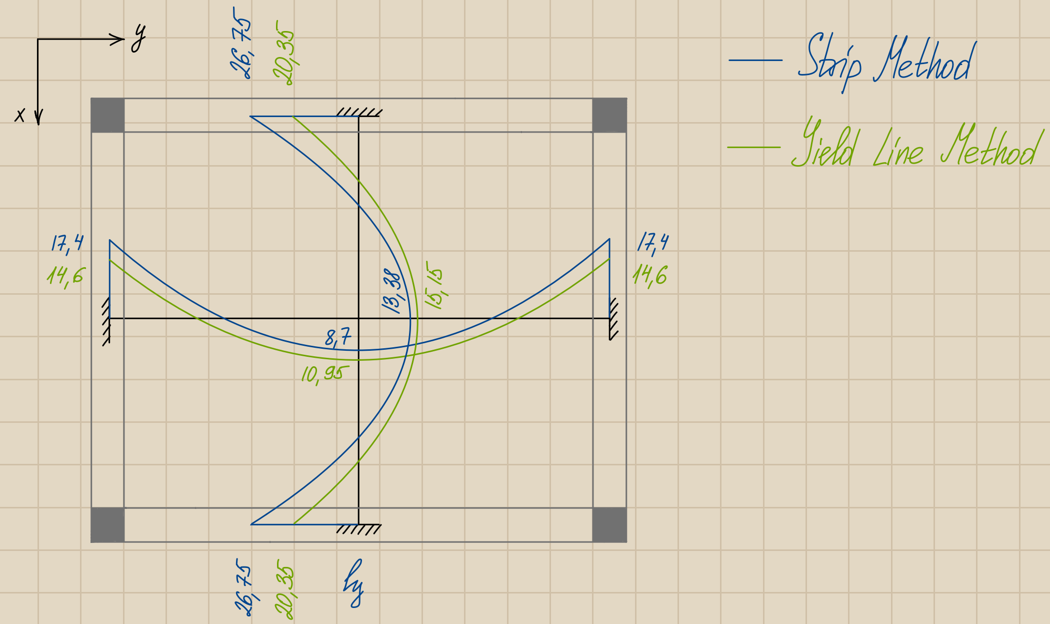
$m_{xe}=\beta_{xe}\cdot m_0=-0{,}0446\cdot 456{,}35=-20{,}35\ kN$

$m_{xm}=\beta_{xm}\cdot m_0=0{,}0332\ 456{,}35=15{,}15\ kN$

$m_{ye}=\beta_{ye}\cdot m_0=-0{,}032\cdot 456{,}35=-14{,}60\ kN$

$m_{ym}=\beta_{ym}\cdot m_0=0{,}024\cdot 456{,}35=10{,}95\ kN$

5. Comparison of moments



6. Preliminary check of slab depth

$M_{Ed,max} = 20{,}35\ kNm$

1) Area of reinforcement

$c = 25\ mm$

$\phi = 10\ mm$

$d = 190 - 25 - 5 = 160\ mm$

$$a_{s,rqd} = \frac{M_{Ed,max}}{0{,}9d \cdot f_{yd}} = \frac{20{,}35 \cdot 10^6}{0{,}9 \cdot 0{,}16 \cdot 434{,}78 \cdot 10^3} = 325\ mm^2$$

$$a_{s,min} = \max\left(0{,}26 \cdot \frac{f_{ctm}}{f_{yk}} \cdot b \cdot d;\ 0{,}0013\, b \cdot d\right) =$$

$$= \max\left(0{,}26 \cdot \frac{2{,}6}{500} \cdot 1000 \cdot 160;\ 0{,}0013 \cdot 1000 \cdot 160\right) = \max\left(216{,}3\ mm^2;\ 208\ mm^2\right) =$$

$$= 216{,}3\ mm^2$$

$$a_{s,max} = 0{,}04\, b \cdot d = 0{,}04 \cdot 1000 \cdot 160 = 6400\ mm^2$$

$216{,}3 < 325 < 6400$ ✓

2) Compressed zone

Depth of compression estimation:

$$x = \frac{1{,}2\, a_{s,rqd} \cdot f_{yd}}{0{,}8\, b \cdot f_{cd}} = \frac{1{,}2 \cdot 325 \cdot 10^{-6} \cdot 434{,}78 \cdot 10^3}{0{,}8 \cdot 1 \cdot 16{,}67 \cdot 10^3} = 0{,}013\, m = 13\ mm$$

$$\frac{x}{d} = \frac{13}{160} = 0{,}081 < 0{,}45$$ ✓

3) Span/depth ratio

$\lambda \leq \lambda_d$

$$\lambda_x = \frac{5{,}4}{0{,}16} = 33{,}75$$

$$\lambda_y = \frac{6{,}7}{0{,}16} = 41{,}875$$

$$\lambda_d = k_{c1} \cdot k_{c2} \cdot k_{c3} \cdot \lambda_{d,tab}$$

$$k_{c1} = k_{c2} = 1$$

$K_{c3} = \frac{500}{f_{yk}} \cdot \frac{a_{s,prov}}{a_{s,rqd}}$

$K_{c3} = \frac{500 \cdot 1{,}2}{500} = 1{,}2$

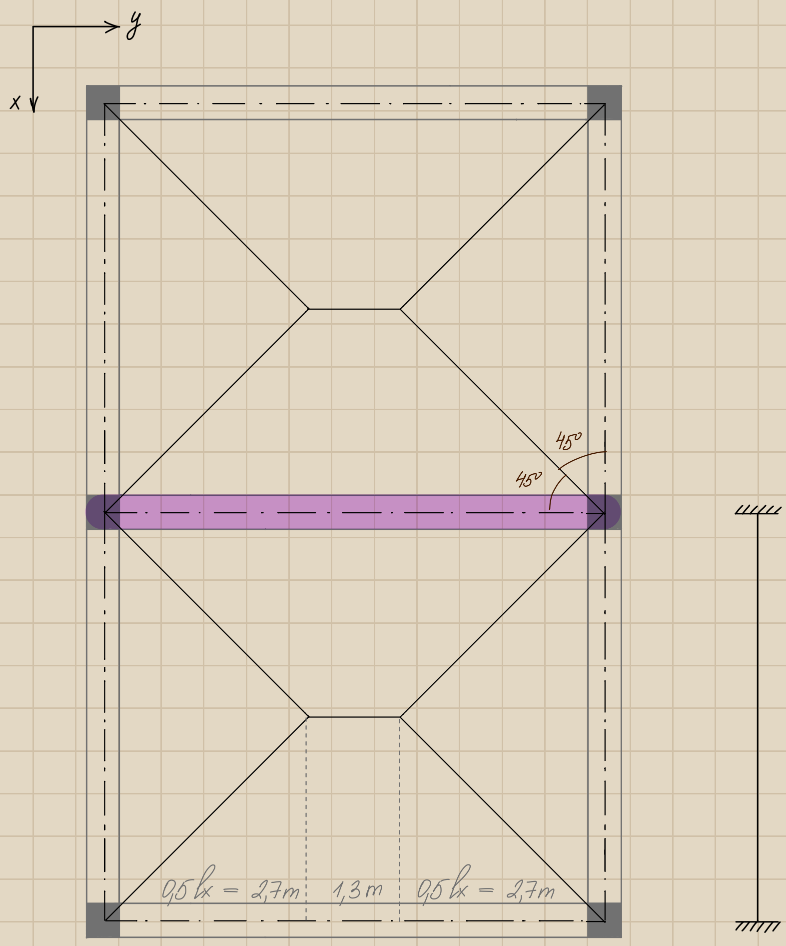
$\frac{a_{s,prov}}{bh} = \frac{1{,}2 \cdot 325}{1000 \cdot 190} = 0{,}002 = 0{,}2\,\%$ => take 22,5 for C25/30

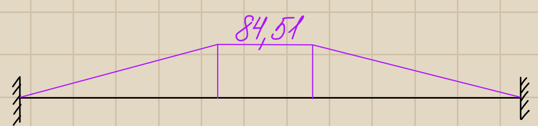
$\lambda_{d,tab} = 22{,}5$

$\lambda_d = 1 \cdot 1 \cdot 1{,}2 \cdot 22{,}5 = 27$ X

Neither λ_x nor λ_y fulfill the requirement. I would suggest increasing the slab thickness or decreasing the span.

7. Load of beam





$f = f_d \cdot 0{,}5 l_x \cdot 2 = 15{,}65 \cdot 0{,}5 \cdot 5{,}4 \cdot 2 = 84{,}51$ kN/m