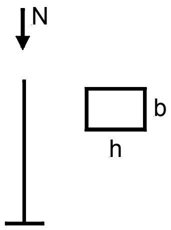
Euro-Code 2

Beam

Pos.: Concrete coulmn without buckling:



Section properties:

Column width b =	25,00 cm
Column thick h =	75,00 cm
Assumed bar size d_{s1} =	2,50 cm
nom_c =	3,50 cm

Design forces:

N_{sd} =	3000 kN

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	20,00 N/mm²
E_s =			200,00 kN/mm²
ε_s=			-2,00 $*10^{-3}$
γ_s =			1,15
σ_{su} =	$E_s * \varepsilon_s$	=	-0,40 N/mm²

Analysis:

A_s=	$((-N_{sd}*10^3/(\sigma_{su}/\gamma_s))-(0,85*f_{cd}/ABS(\sigma_{su}/\gamma_s))*b*10^2*h)/10^2$	=	-5390,62 cm²
min_A_s=	$(MAX(0,15*10^3*(N_{sd}/f_{yd});0,3*b*h))/10^2$	=	10,35 cm²
req_A_s=	MAX(A_s;min_A_s)	=	**10,35 cm²**

Provide six 16 mm bars

d_s =	SEL("reinf/As"; ds;)	=	16 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s=d_s; As≥req_A_s)	=	6 ∅ 16
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	12,06 cm²

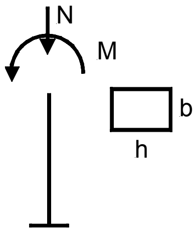
req_A_s / prov_A_s = **0,86 < 1**

min_d_{sw}=			6,00 mm with d_{sl}<20mm
min_d_{sw}=	0,25 * d_s	=	4,00 mm with d_{sl}>25mm
min_d_{sw}=			5,00 mm for mesh reinforceme

max_s_w= MIN(12*d_s;b;h;30) = 25,00 cm

Only closed links are recommended. The hooks are to be curtailed.

Pos.: Concrete column with bending moment without buckling:



Section properties:

Column width b =	25,00 cm
Column thick h =	75,00 cm
Assumed bar size d_{s1} =	2,50 cm
nom_c =	3,50 cm

Design forces:

N_{sd} =	1980 kN
M_{sd} =	563 kNm

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	20,00 N/mm²

Analysis:

d_1 =	nom_c + d_{s1}	=	6,00 cm
d_1 / h		=	0,080 ~ 0,1
v_{sd} =	-(N_{sd} * 10) / (b * h * f_{cd})	=	-0,528
μ_{sd} =	10³ * (ABS(M_{sd})) / (b * h² * f_{cd})	=	0,200

From the interactive diagram

ω_{tot} = 0,30

A_{s1} =	ω_{tot} / 2 * b * h / (f_{yd} / f_{cd})	=	12,94 cm²
A_{s2} =	A_{s1}	=	12,94 cm²

Provide two 25 mm and two 20 mm bars

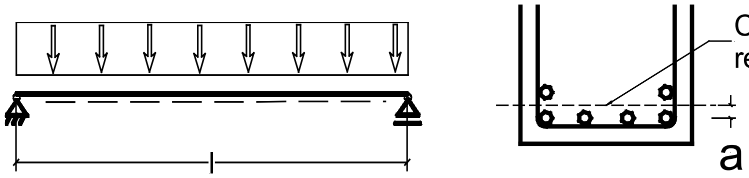
d_{s1} =	SEL("reinf/As"; ds;)	=	20 mm
$A_{s,sel1}$ =	SEL("reinf/As"; Name; d_s=d_{s1};)	=	2 Ø 20
prov_A_{s1} =	TAB("reinf/As"; As; Name=$A_{s,sel1}$)	=	6,28 cm²
d_{s2} =	SEL("reinf/As"; ds;)	=	25 mm
$A_{s,sel2}$ =	SEL("reinf/As"; Name; d_s=d_{s2}; As≥A_{s1}-prov_A_{s1})	=	2 Ø 25
prov_A_{s2} =	TAB("reinf/As"; As; Name=$A_{s,sel2}$)	=	9,82 cm²
min_d_{sl} =	MIN(d_{s1} ;d_{s2})	=	20,00 mm
prov_A_s=	prov_A_{s1} + prov_A_{s2}	=	16,10 cm²

A_{s1} / prov_A_s = **0,80 < 1**

min_d_{sw}=			6,00 mm with d_{sl}<20mm
min_d_{sw}=	0,25*min_d_{sl}	=	5,00 mm with d_{sl}>25mm
min_d_{sw}=			5,00 mm for mesh reinforceme
max_s_w=	MIN(12*min_d_{sl};b;h;30)	=	25,00 cm

Only closed links are recommended. The hooks are to be curtailed.

Pos.: Single beam:



Section properties:

Span length L =	2,80 m
Width b =	0,24 m
Depth h =	0,58 m
Axis of bending tension reinforcement a =	0,02 m
Assumed bar size d_{s1} =	0,025 m
nom_c =	0,035 m

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,28 N/mm²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	20,00 N/mm²

Partial safety factors:

γ_G =	1,35
γ_Q =	1,50

Load on span:

from dead load:	b * h * 25	=	3,48 kN/m
from nib:	b * 1,35 * 25	=	8,10 kN/m
from Pos. 201:			48,50 kN/m
		max q_g=	**60,08 kN/m**
live load from Pos1:			20,00 kN/m
live load from Pos2:			37,50 kN/m
		max q_q=	**57,50 kN/m**

Design Calculation:

V_G =	q_g * L/2	=	84,11 kN
V_Q =	q_q * L/2	=	80,50 kN
M_G =	q_g * L² / 8	=	58,88 kNm
M_Q =	q_q * L² / 8	=	56,35 kNm
M_{sd} =	γ_G * M_G + γ_Q * M_Q	=	164,01 kNm
d =	h - nom_c - a - d_{s1} / 2	=	0,512 m

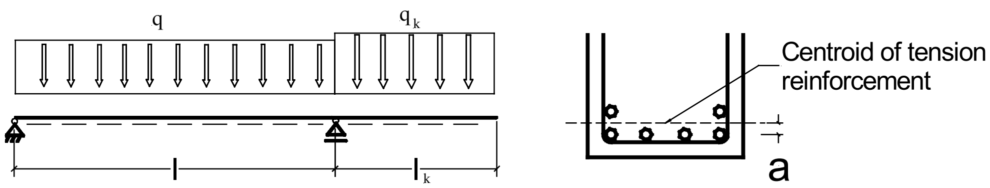
z_{s1} =	d - h / 2	=	0,22 m
$M_{sd,s}$ =	$ABS(M_{sd})$	=	164,01 kNm
$\mu_{Sd,s}$ =	$M_{sd,s} / 10^3 / (b * d^2 * f_{cd})$	=	0,130
ω =	TAB("reinf/Ecmy"; ω; $\mu=\mu_{Sd,s}$)	=	0,142
req_A_s=	$(\omega*d*100*b*100*f_{cd})/f_{yd}$	=	8,03 cm²

Provide two 25 mm bars

Bar size d_s =	SEL("reinf/As"; ds;)	=	25 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	2 Ø 25
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	9,82 cm²

req_A_s / prov_A_s = **0,82 < 1**

Pos.: Single-span with right cantilever:



Section properties:

Span length l =	2,80 m
Length of cantilever l_c =	1,60 m
Width b =	0,24 m
Depth h =	0,58 m
Axis of bending tension reinforcement a =	0,02 m
Assumed bar size d_{s1} =	0,025 m
nom_c =	0,035 m

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,28 N/mm²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	20,00 N/mm²

Partial safety factors:

γ_G =	1,35
γ_Q =	1,50

Loads on span:

from dead load:	b * h * 25	=	3,48 kN/m
from nib:	b * 1,35 * 25	=	8,10 kN/m
from Pos. 201:			48,50 kN/m
		max q_g=	**60,08 kN/m**

live load from Pos1:		20,00 kN/m
live load from Pos2:		74,50 kN/m
	max q_p=	**94,50 kN/m**

Loads on cantilever:

from dead load:	b * h * 25	=	3,48 kN/m
from nib:	b * 1,35 * 25	=	8,10 kN/m
from Pos. 201:			48,50 kN/m
		max q_{gc}=	**60,08 kN/m**

live load from Pos1:		40,00 kN/m
live load from Pos2:		70,50 kN/m
	max q_{pc}=	**110,50 kN/m**

Design Calculation:

M_{gk} =	$-q_{gc} * l_c^2 / 2$	=	-76,90 kNm
M_{pk} =	$-q_{pc} * l_c^2 / 2$	=	-141,44 kNm
M_{gfeld} =	$q_g * l^2 / 8$	=	58,88 kNm
M_{pfeld} =	$q_p * l^2 / 8$	=	92,61 kNm

Design calculation cantilever:

M_{sdk} =	$\gamma_G * M_{gk} + \gamma_Q * M_{pk}$	=	-315,98 kNm
d =	h - nom_c - a - d_{s1} / 2	=	0,512 m
z_{s1} =	d - h / 2	=	0,22 m
$M_{sdk,s}$ =	ABS(M_{sdk})	=	315,98 kNm
$\mu_{Sdk,s}$ =	$M_{sdk,s} / 10^3 / (b * d^2 * f_{cd})$	=	0,251
ω =	TAB("reinf/Ecmy"; ω; $\mu=\mu_{Sdk,s}$)	=	0,309
req_A_s=	$(\omega*d*100*b*100*f_{cd})/f_{yd}$	=	17,47 cm²

Provide five 25 mm bars

Bar size d_s =	SEL("reinf/As"; ds;)	=	25 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	5 Ø 25
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	24,54 cm²

req_A_s / prov_A_s = **0,71 < 1**

Design calculation span:

$M_{sdf,min}$ =	$M_{gfeld} + \gamma_G * M_{sdk} / 2$	=	-154,41 kNm
d =	h - nom_c - a - d_{s1} / 2	=	0,512 m
z_{s1} =	d - h / 2	=	0,22 m
$M_{sdf,min,s}$ =	ABS($M_{sdf,min}$)	=	154,41 kNm
$\mu_{Sdf,min,s}$ =	$M_{sdf,min,s} / 10^3 / (b * d^2 * f_{cd})$	=	0,123
ω =	TAB("reinf/Ecmy"; ω; $\mu=\mu_{Sdf,min,s}$)	=	0,134

$req\_A_s =$ $(\omega * d * 100 * b * 100 * f_{cd})/f_{yd}$ = 7,57 cm²

Provide two 25 mm bars

Bar size d_s = SEL("reinf/As"; ds;) = 25 mm

$A_{s,sel}$ = SEL("reinf/As"; Name; $d_s = d_s$; As≥req_A_s) = 2 Ø 25

$prov\_A_s$ = TAB("reinf/As"; As; Name=$A_{s,sel}$) = 9,82 cm²

$req\_A_s / prov\_A_s$ = **<u>0,77 < 1</u>**

$M_{sdf,max} = \gamma_G * M_{gfeld} + \gamma_Q * M_{pfeld} + M_{sdk} / 2$ = 60,41 kNm

$d = h - nom\_c - a - d_{s1} / 2$ = 0,512 m

$z_{s1} = d - h / 2$ = 0,22 m

$M_{sdf,max,s} = ABS(M_{sdf,max})$ = 60,41 kNm

$\mu_{Sdf,max,s} = M_{sdf,max,s} / 10^3 / (b * d^2 * f_{cd})$ = 0,048

ω = TAB("reinf/Ecmy"; ω; $\mu = \mu_{Sdf,max,s}$) = 0,050

$req\_A_s =$ $(\omega * d * 100 * b * 100 * f_{cd})/f_{yd}$ = 2,83 cm²

Provide three 12 mm bars

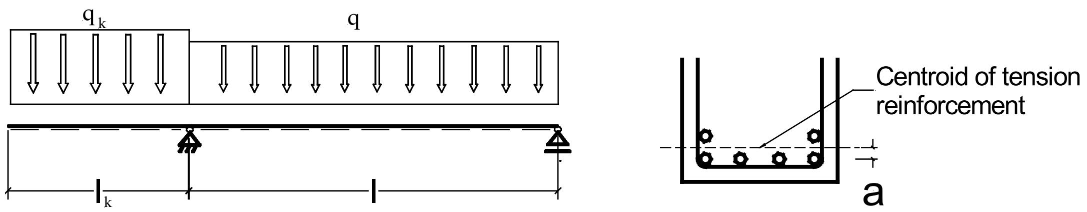
Bar size d_s = SEL("reinf/As"; ds;) = 12 mm

$A_{s,sel}$ = SEL("reinf/As"; Name; $d_s = d_s$; As≥req_A_s) = 3 Ø 12

$prov\_A_s$ = TAB("reinf/As"; As; Name=$A_{s,sel}$) = 3,39 cm²

$req\_A_s / prov\_A_s$ = **<u>0,83 < 1</u>**

Pos.: Single-span with left cantilever:



Section properties:

Span length l =	2,80 m
Length of cantilever l_c =	1,60 m
Width b =	0,24 m
Depth h =	0,58 m
Axis of bending tension reinforcement a =	0,02 m
Assumed bar size d_{s1} =	0,025 m
nom_c =	0,035 m

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,28 N/mm²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	20,00 N/mm²

Partial safety factors:

γ_G =	1,35
γ_Q =	1,50

Loads on span:

from dead load:	b * h * 25	=	3,48 kN/m
from nib:	b * 1,35 * 25	=	8,10 kN/m
from Pos. 201:			48,50 kN/m
		max q_g=	**60,08 kN/m**

live load from Pos1:	20,00 kN/m
live load from Pos2:	74,50 kN/m
max q_p=	**94,50 kN/m**

Loads on cantilever:

from dead load:	b * h * 25	=	3,48 kN/m
from nib:	b * 1,35 * 25	=	8,10 kN/m
from Pos. 201:			48,50 kN/m
		max q_{gc}=	**60,08 kN/m**

live load from Pos1:			40,00 kN/m
live load from Pos2:			70,50 kN/m
		max q_{pc}=	**110,50 kN/m**

Design Calculation:

M_{gk} =	$-q_{gc} * l_c^2 / 2$	=	-76,90 kNm
M_{pk} =	$-q_{pc} * l_c^2 / 2$	=	-141,44 kNm
M_{gfeld} =	$q_g * l^2 / 8$	=	58,88 kNm
M_{pfeld} =	$q_p * l^2 / 8$	=	92,61 kNm

Design Calculation cantilever:

M_{sdk} =	$\gamma_G * M_{gk} + \gamma_Q * M_{pk}$	=	-315,98 kNm
d =	$h - nom\_c - a - d_{s1} / 2$	=	0,512 m
z_{s1} =	d - h / 2	=	0,22 m
$M_{sdk,s}$ =	$ABS(M_{sdk})$	=	315,98 kNm
$\mu_{Sdk,s}$ =	$M_{sdk,s} / 10^3 / (b * d^2 * f_{cd})$	=	0,251
ω =	TAB("reinf/Ecmy"; ω; $\mu=\mu_{Sdk,s}$)	=	0,309
req_A_s=	$(\omega*d*100*b*100*f_{cd})/f_{yd}$	=	17,47 cm²

Provide five 25 mm bars

Bar size d_s =	SEL("reinf/As"; ds;)	=	25 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	5 Ø 25
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	24,54 cm²

req_A_s / prov_A_s = **0,71 < 1**

Design calculation span:

$M_{sdf,min}$ =	$M_{gfeld} + \gamma_G * M_{sdk} / 2$	=	-154,41 kNm
d =	$h - nom\_c - a - d_{s1} / 2$	=	0,512 m
z_{s1} =	d - h / 2	=	0,22 m
$M_{sdf,min,s}$ =	$ABS(M_{sdf,min})$	=	154,41 kNm
$\mu_{Sdf,min,s}$ =	$M_{sdf,min,s} / 10^3 / (b * d^2 * f_{cd})$	=	0,123
ω =	TAB("reinf/Ecmy"; ω; $\mu=\mu_{Sdf,min,s}$)	=	0,134

req_A_s=	$(\omega*d*100*b*100*f_{cd})/f_{yd}$	=	7,57 cm²

Provide two 25 mm bars

Bar size d_s =	SEL("reinf/As"; ds;)	=	25 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	2 Ø 25
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	9,82 cm²

req_A_s / prov_A_s = **0,77 < 1**

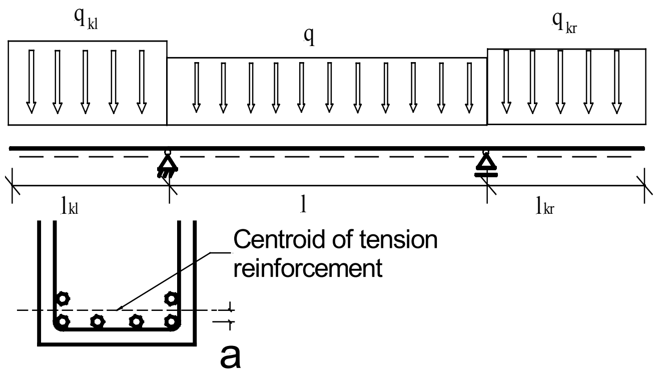
$M_{sdf,max}$ =	$\gamma_G * M_{gfeld} + \gamma_Q * M_{pfeld} + M_{sdk} / 2$	=	60,41 kNm
d =	$h - nom\_c - a - d_{s1} / 2$	=	0,512 m
z_{s1} =	d - h / 2	=	0,22 m
$M_{sdf,max,s}$ =	$ABS(M_{sdf,max})$	=	60,41 kNm
$\mu_{Sdf,max,s}$ =	$M_{sdf,max,s} / 10^3 / (b * d^2 * f_{cd})$	=	0,048
ω =	TAB("reinf/Ecmy"; ω; $\mu=\mu_{Sdf,max,s}$)	=	0,050
req_A_s=	$(\omega*d*100*b*100*f_{cd})/f_{yd}$	=	2,83 cm²

Provide three 12 mm bars

Bar size d_s =	SEL("reinf/As"; ds;)	=	12 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	3 Ø 12
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	3,39 cm²

req_A_s / prov_A_s = **0,83 < 1**

Pos.: Single-span with cantilever^s:



Section properties:

Span length l =		2,80 m
Length of cantilever l_{cl} =		0,80 m
Length of cantilever l_{cr} =		1,00 m
Width b =	0,24 m	
Depth h =	0,55 m	
Axis of bending tension reinforcement a =	0,02 m	
Assumed bar size d_{s1} =	0,025 m	
nom_c =	0,035 m	

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,28 N/mm²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	20,00 N/mm²

Partial safety factors:

γ_G =	1,35
γ_Q =	1,50

Loads on span:

from dead load:	b * h * 25	=	3,30 kN/m
from nib:	b * 1,35 * 25	=	8,10 kN/m
from Pos. 201:			48,50 kN/m
		max q_{gf}=	**59,90 kN/m**
live load from Pos1:			20,00 kN/m
live load from Pos2:			74,50 kN/m
		max q_{qf}=	**94,50 kN/m**

Loads on left cantilever:

from dead load:	b * h * 25	=	3,30 kN/m
from nib:	b * 1,35 * 25	=	8,10 kN/m
from Pos. 201:			48,50 kN/m
		max q_{gcl}=	**59,90 kN/m**
live load from Pos1:			40,00 kN/m
live load from Pos2:			70,50 kN/m
		max q_{qcl}=	**110,50 kN/m**

Loads on right cantilever:

from dead load:	b * h * 25	=	3,30 kN/m
from nib:	b * 1,35 * 25	=	8,10 kN/m
from Pos. 201:			48,50 kN/m
		max q_{gcr}=	**59,90 kN/m**
live load from Pos1:			40,00 kN/m
live load from Pos2:			70,50 kN/m
		max q_{qcr}=	**110,50 kN/m**

Design Calculation:

M_{gkl} =	$-q_{gcl} * l_{cl}^2 / 2$	=	-19,17 kNm
M_{qkl} =	$-q_{qcl} * l_{cl}^2 / 2$	=	-35,36 kNm
M_{gkr} =	$-q_{gcr} * l_{cr}^2 / 2$	=	-29,95 kNm
M_{qkr} =	$-q_{qcr} * l_{cr}^2 / 2$	=	-55,25 kNm
M_{gfeld} =	$q_{gf} * l^2 / 8$	=	58,70 kNm
M_{qfeld} =	$q_{qf} * l^2 / 8$	=	92,61 kNm

Design calculation left cantilever:

M_{sdkl} =	$\gamma_G * M_{gkl} + \gamma_Q * M_{qkl}$	=	-78,92 kNm
d =	h - nom_c - a - d_{s1} / 2	=	0,482 m
z_{s1} =	d - h / 2	=	0,21 m
$M_{sdkl,s}$ =	ABS(M_{sdkl})	=	78,92 kNm
$\mu_{Sdkl,s}$ =	$M_{sdkl,s} / 10^3 / (b * d^2 * f_{cd})$	=	0,071
ω =	TAB("reinf/Ecmy"; ω; $\mu=\mu_{Sdkl,s}$)	=	0,074

req_A_s=	$(\omega*d*100*b*100*f_{cd})/f_{yd}$	=	3,94 cm²

Provide three 16 mm bars

Bar size d_s =	SEL("reinf/As"; ds;)	=	16 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	3 Ø 16
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	6,03 cm²

req_A_s / prov_A_s = **0,65 < 1**

Design calculation right cantilever:

M_{sdkr} =	$\gamma_G * M_{gkr} + \gamma_Q * M_{qkr}$	=	-123,31 kNm
d =	h - nom_c - a - d_{s1} / 2	=	0,482 m
z_{s1} =	d - h / 2	=	0,21 m
$M_{sdkr,s}$ =	ABS(M_{sdkr})	=	123,31 kNm
$\mu_{Sdkr,s}$ =	$M_{sdkr,s}$ / 10³ / (b * d² * f_{cd})	=	0,111
ω =	TAB("reinf/Ecmy"; ω; μ=$\mu_{Sdkr,s}$)	=	0,120
req_A_s=	$(\omega*d*100*b*100*f_{cd})/f_{yd}$	=	6,39 cm²

Provide five 14 mm bars

Bar size d_s =	SEL("reinf/As"; ds;)	=	14 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	5 Ø 14
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	7,70 cm²

req_A_s / prov_A_s = **0,83 < 1**

Design calculation span:

$M_{sdf,min}$ =	γ_G * M_{gfeld} + (M_{sdkl} + M_{sdkr}) / 2	=	-21,87 kNm
d =	h - nom_c - a - d_{s1} / 2	=	0,482 m
z_{s1} =	d - h / 2	=	0,21 m
$M_{sdf,min,s}$ =	ABS($M_{sdf,min}$)	=	21,87 kNm
$\mu_{Sdf,min,s}$ =	$M_{sdf,min,s}$ / 10³ / (b * d² * f_{cd})	=	0,020
ω =	TAB("reinf/Ecmy"; ω; μ=$\mu_{Sdf,min,s}$)	=	0,020
req_A_s=	(ω*d*100*b*100*f_{cd})/f_{yd}	=	1,06 cm²

Provide two 14 mm bars

Bar size d_s =	SEL("reinf/As"; ds;)	=	14 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	2 Ø 14
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	3,08 cm²

req_A_s / prov_A_s = **0,34 < 1**

$M_{sdf,max}$ =	γ_G * M_{gfeld} + γ_Q * M_{qfeld} + (M_{sdkl} + M_{sdkr}) / 2	=	117,05 kNm
d =	h - nom_c - a - d_{s1} / 2	=	0,482 m
z_{s1} =	d - h / 2	=	0,21 m
$M_{sdf,max,s}$ =	ABS($M_{sdf,max}$)	=	117,05 kNm
$\mu_{Sdf,max,s}$ =	$M_{sdf,max,s}$ / 10³ / (b * d² * f_{cd})	=	0,105
ω =	TAB("reinf/Ecmy"; ω; μ=$\mu_{Sdf,max,s}$)	=	0,113
req_A_s=	(ω*d*100*b*100*f_{cd})/f_{yd}	=	6,01 cm²

Provide four 16 mm bars

Bar size d_s =	SEL("reinf/As"; ds;)	=	16 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	4 Ø 16
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	8,04 cm²

req_A_s / prov_A_s = **0,75 < 1**

Design Calculations

Analysis for shearing:

Section properties:

Support width a_1 =	0,30 m
Rib width b_w =	0,30 m
Slab thickness h_f =	0,15 m
Rib depth d =	0,675 m
Tension reinforcement req_A_{s1} =	13,23 cm²
sel. Θ =	30,00 °

Loads:

q_q =	12,40 kN/m
q_g =	62,30 kN/m
V_G =	300,00 kN
V_Q =	63,00 kN

Materials, stresses and partial safety factors:

Concrete =	SEL("concrete/EC"; Name;)	=	C20/25
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	20,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,24 N/mm²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	13,33 N/mm²
γ_G=			1,35
γ_Q=			1,50

Shear Analysis:

max_V =	$V_G * \gamma_G + V_Q * \gamma_Q$	=	499,50 kN
x_v =	a_1 / 2 + d	=	0,825 m
Effective shearing force:			
V_{sd} =	max_V - ($q_g * \gamma_G + q_q * \gamma_Q$) * x_v	=	414,77 kN
4 / 7 / (1 / TAN(Θ))		=	**<u>0,33 < 1</u>**
(1 / TAN(Θ)) / 7 / 4		=	**<u>0,06 < 1</u>**
v =	0,7 - f_{ck} / 200	=	0,60 N/mm² > 0,5
For flanged beams:			
z_r =	d - h_f / 2	=	0,60 m
For other sections:			
z_r =	0,9 * d	=	0,61 m
V_{Rd2} =	(v * f_{cd} * b_w * z_r) / (1 / TAN(Θ) + TAN(Θ)) * 10³	=	633,77 kN
V_{sd} / V_{Rd2}		=	**<u>0,65 < 1</u>**

req_a_{sw} = 10 * V_{sd} / (z_r * f_{yd}) * (TAN(Θ)) = 9,03 cm²/m

Provide links of size 10 mm (double-shear)

d_s =	SEL("reinf/AsArea"; ds;)	=	10,00 mm
a_s =	SEL("reinf/AsArea";Name;d_s=d_s;a_s≥req_a_{sw}/2)	=	∅ 10 / e = 9
$prov\_a_{sw}$=	2 * TAB("reinf/AsArea"; as; Name=a_s)	=	17,46 cm²/m

req_a_{sw} / $prov\_a_{sw}$ = **0,52 < 1**

V_{sd} / (0,67 * V_{Rd2}) = **0,98 < 1**

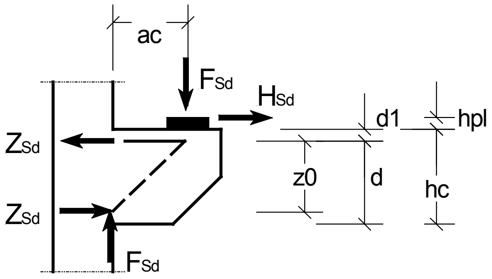
Spacing for links

max_s_w = 0,3*d = 0,203 m > 0,2m

s_w = 0,125 m

s_w / max_s_w = **0,62 < 1**

Concrete corbel:



Section properties:

Shear span a_c =	40,00 cm
Corbel depth h_c =	65,00 cm
Thickness of bearing plate h_{pl} =	4,00 cm
Center of reinforcement d_1 =	4,00 cm
Corbel width b_w =	40,00 cm
Area of bearing plate A_{pl} =	45,00 cm²
generally ν =	0,60

Materials, stresses and partial safety factors:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	420 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	420 MN/m²
τ_{Rd} =	TAB("Concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,28 N/mm²
f_{yd}=	f_{yk} / 1,15	=	365,22 N/mm²
f_{cd}=	f_{ck} / 1,5	=	20,00 N/mm²

Loads:

F_{Sd} =	400,00 kN
H_{Sd} =	45,00 kN

Design Calculation:

a_c / h_c = **0,62 < 1 otherwise design as cantilever**

H_{Sd} =	MAX(0,2*F_{Sd} ; H_{Sd})	=	80,00 kN
d =	$h_c - d_1$	=	61,00 cm
V_{Rd2} =	0,05* ν * f_{cd} * b_w * 0,9 * d	=	1317,60 kN
F_{Sd} / V_{Rd2}		=	**0,30 < 1**
z_0 =	d * (1 - 0,4*F_{Sd} / V_{Rd2})	=	53,59 cm
Z_{Sd} =	F_{Sd}*a_c /z_0 + H_{Sd}*(h_{pl}+d_1+z_0)/z_0	=	390,51 kN
A_s =	10 * Z_{Sd} / f_{yd}	=	10,69 cm²

Provide four 20 mm bars

$d_{s,sel}$ =	SEL("reinf/As"; ds;)	=	20 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; ds=$d_{s,sel}$; A_s≥A_s)	=	4 Ø 20
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	12,57 cm²

n =	TAB("reinf/As"; n; Name=$A_{s,sel}$)	=	4

Main tension reinforcement:

A_s / prov_A_s	=	**0,85 < 1**	
a_c / (0,5*h_c)	=	**1,23 > 1**	
k =	MAX(1; (160 - d) / 100)	=	1,00
ρ =	A_s /(b_w * d)	=	0,00438
V_{Rd1} =	(τ_{Rd}*k*(1,2+40*ρ))*b_w*d	=	939,54 kN
F_{Sd} / V_{Rd1}	=	**0,43 < 1**	

Vertical links:

A_{sw} =	0,7 * F_{Sd} / f_{yd}	=	0,77 cm²

Provide 2 links of size 8 mm (double-shear)

$d_{s,sel}$ =	SEL("reinf/As"; ds;)	=	8 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = $d_{s,sel}$; As≥A_{sw})	=	2 Ø 8
prov_A_{sw} =	2 * TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	2,02 cm²
n =	TAB("reinf/As"; n; Name=$A_{s,sel}$)	=	2

Main tension reinforcement:

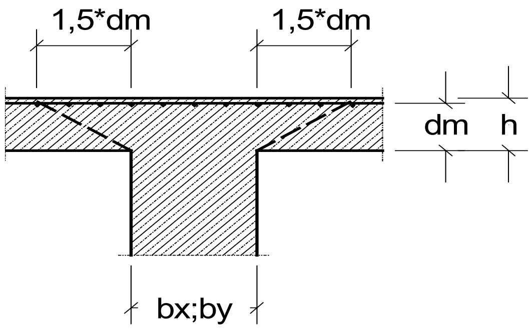
A_{sw} / prov_A_{sw} = **0,38 < 1**

The links are closed and to be placed vertically.

Load pressure:

(F_{Sd} / A_{pl}) / (ν * f_{cd}) = **0,74 < 1**

Punching shear analysis in a flat slap:



Section properties:

Slap thickness h =	24,00 cm
Effective depth d_x =	21,50 cm
Effective depth d_y =	20,50 cm
Span perimeter l_x =	6,00 m
Span perimeter l_y =	6,50 m
column width b_x =	35,00 cm
column width b_y =	35,00 cm

Loads:

g_k =	7,10 kN/m²
q_k =	5,25 kN/m²

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,28 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	20,00 N/mm²
γ_G=			1,35
γ_Q=			1,50

Top reinforcement in slab:

Bar size d_s=	SEL("reinf/AsArea"; ds;)	=	20 mm
spacing s =	SEL("reinf/AsArea"; e;)	=	10,00 cm

Design Calculation:

A_{sx} =	$(d_s/20)^2 * \pi * 100 / s$	=	31,42 cm²/m
d_m =	$(d_x + d_y) / 2$	=	21,00 cm

Punching shear analysis:
Shearing force for design:

V_{sd} = $(\gamma_G * g_k + \gamma_Q * q_k) * l_x * l_y$ = 680,94 kN

Critical perimeter:

u = $(2 * (b_x + b_y) + 2 * 1,5 * d_m * \pi) / 100$ = 3,38 m

Shearing force per unit length along the critical perimeter:

for internal columns β = 1,15

v_{Sd} = $V_{sd} * \beta / u$ = 231,68 kN/m

Maximum bearing capacity of slab per unit length without punching shear reinforcement:

$k =$ MAX(1,6 - d_m/100;1) = 1,39

$\rho_1 =$ A_{sx} / (d_m * 100) = 0,0150 > 0,0050

$\nu_{Rd1} =$ τ_{Rd} * k * (1,2 + 40 * ρ_1) * d_m / 100 = 0,147 MN/m

$\nu_{Sd} / 10^3 / \nu_{Rd1}$ = **1,58 > 1 !!!**

⇒ compressive reinforcement is necessary!

$\nu_{Rd2} =$ 1,6 * ν_{Rd1} = 0,235 MN/m

Maximum bearing capacity of slab per unit length with punching shear reinforcement:

$\nu_{Sd} / 10^3 / \nu_{Rd2}$ = **0,99 < 1**

Reinforcement for punching shear:

Inclination of links α = 45,00 °

$A_{sw} =$ 10^4 * u * ($\nu_{Sd}/10^3$ - ν_{Rd1}) / (f_{yd} * SIN(α)) = 9,30986 cm²

Minimum reinforcement:

$A_{crit} =$ b_x*b_y + (2*b_x+2*b_y) *1,5*d_m +(1,5*d_m)²*π = 8752,24 cm²

$A_{load} =$ b_x * b_y = 1225,00 cm²

$\rho_w =$ A_{sw} * SIN(α) / (A_{crit} - A_{load}) = 0,00087

min_ρ_w = WENN(f_{ck}<250,00007;WENN(f_{ck}<40;0,0011;0,0013)) = 0,00110

min_ρ_w = 0,6 * min_ρ_w = 0,00066

$A_{sw} =$ min_ρ_w * (A_{crit} - A_{load}) / SIN(α) = 7,026 cm²

Provide links (double-shear):

$d_{s,sel} =$ SEL("reinf/As"; ds;) = 8 mm

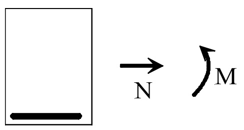
$A_{s,sel} =$ SEL("reinf/As"; Name; ds=$d_{s,sel}$; $A_s \geq A_{sw}/2$) = 8 Ø 8

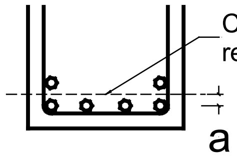
prov_A_s = 2 * TAB("reinf/As"; As; Name=$A_{s,sel}$) = 8,04 cm²

Structural analysis:

A_{sw} / prov_A_s = **0,87 < 1**

Rectangular section using the kh-method





Section properties:

Width b =	0,25 m
Depth h =	0,75 m
Concrete cover nom_c =	0,035 m
Distance between centre of tension and lowest bar a =	0,020 m

Bar size d_s =	SEL("reinf/As"; ds;)	=	25,0 mm

Loads:

M_G=	250,00 kNm
M_Q=	150,00 kNm
N_G=	1,00 kN
N_Q=	0,00 kN

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²

Partial safety faktors:

γ_s=	1,15
γ_G=	1,35
γ_Q=	1,50

Design Calculation:

f_{yd} =	f_{yk} / γ_s	=	434,78 kN/cm²
N_{sd} =	$\gamma_G * N_G + \gamma_Q * N_Q$	=	1,35 kN
M_{sd} =	$\gamma_G * M_G + \gamma_Q * M_Q$	=	562,50 kNm
d =	$h - nom\_c - d_s/10^3 - a$	=	0,670 m
z_{s1} =	$d - h / 2$	=	0,295 m
$M_{sd,s}$ =	$ABS(M_{sd}) - N_{sd} * z_{s1}$	=	562,10 kNm
k_d =	$d * 100 / \sqrt{(M_{sd,s} / b)}$	=	1,41

k_s =	TAB("reinf/kd"; ks1; Name=Concrete; kd=k_d)	=	2,830
ζ =	TAB("reinf/kd"; ζ; Name=Concrete; kd=k_d)	=	0,813
ξ =	TAB("reinf/kd"; ξ; Name=Concrete; kd=k_d)	=	0,450
ε_{c2} =	TAB("reinf/kd"; ε_{c2}; Name=Concrete; kd=k_d)	=	$-3,500*10^{-3}$
ε_{s1} =	TAB("reinf/kd"; ε_{s1}; Name=Concrete; kd=k_d)	=	$4,270*10^{-3}$

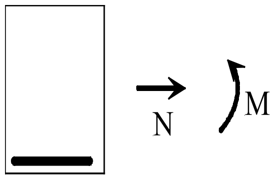
x=	ξ*d	=	0,301 m
z=	ζ*d	=	0,545 m
req_A_s=	$M_{sd,s}$/(d*100)*k_s+10*N_{sd}/f_{yd}	=	23,77 cm²

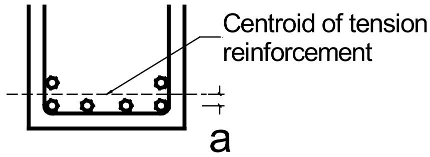
Provide five 25 mm bars

$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	5 Ø 25
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	24,54 cm²

req_A_s / prov_A_s = **<u>0,97 ≤ 1</u>**

Rectangular section:





Section properties:

Width b =	0,25 m
Depth h =	0,75 m
Concrete cover nom_c =	0,035 m
Distance between centre of tension and lowest bar a =	0,010 m

Bar size d_s = SEL("reinf/As"; ds;) = 20,0 mm

Loads:

M_G=	200,00 kNm
M_Q=	100,00 kNm
N_G=	80,00 kN
N_Q=	60,00 kN

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²

Partial safety faktors:

γ_G =	1,35
γ_Q =	1,50
γ_s =	1,15
γ_c =	1,50

Design Calculation:

f_{yd} =	f_{yk} / γ_s	=	434,78 kN/cm²
f_{cd} =	f_{ck} / γ_c	=	20,00 kN/cm²
N_{sd} =	$\gamma_G * N_G + \gamma_Q * N_Q$	=	198,00 kN
M_{sd} =	$\gamma_G * M_G + \gamma_Q * M_Q$	=	420,00 kNm
d =	$h - nom\_c - d_s/10^3 / 2 - a$	=	0,695 m
z_{s1} =	$d - h / 2$	=	0,320 m
$M_{sd,s}$ =	$ABS(M_{sd}) - N_{sd} * z_{s1}$	=	356,64 kNm
$\mu_{Sd,s}$ =	$M_{sd,s} / 10^3 / (b * d^2 * f_{cd})$	=	0,148
ω =	TAB("reinf/Ecmy"; ω; $\mu=\mu_{Sd,s}$)	=	0,164

req_A_s = $(\omega * d * 10^4 * b * f_{cd} + N_{sd} / 10^3) / f_{yd}$ = 13,11 cm²

Provide four 25 mm bars

$A_{s,sel}$ = SEL("reinf/As"; Name; $d_s = d_s$; As≥req_A_s) = 5 Ø 20

$prov\_A_s$ = TAB("reinf/As"; As; Name=$A_{s,sel}$) = 15,71 cm²

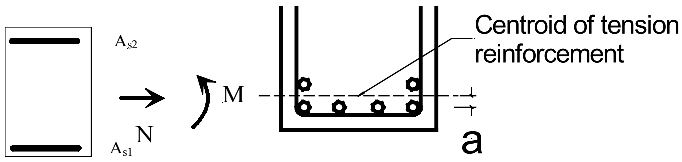
$req\_A_s / prov\_A_s$ = **0,83 < 1**

n = TAB("reinf/As"; n; Name=$A_{s,sel}$) = 5

Section width is appropriate!

b - 2 * nom_c - (2 * n - 1) * $d_s/10^3$ = **0,00 ≥ 0**

Rectangular section with compression reinforcement



Section properties:

Width b =			0,25 m
Depth h =			0,75 m
Concrete cover nom_c =			0,035 m
Distance between centre of tension and lowest bar a =			0,010 m
Bar size d_s =	SEL("reinf/As"; ds;)	=	28,0 mm
Bar size d_{s2} =	SEL("reinf/As"; ds;)	=	12,0 mm

Loads:

M_G=	250,00 kNm
M_Q=	240,00 kNm
N_G=	-80,00 kN
N_Q=	-60,00 kN

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²

Partial safety faktors:

γ_G =	1,35
γ_Q =	1,50
γ_s =	1,15
γ_c =	1,50

Design Calculation:

f_{yd} =	f_{yk} / γ_s	=	434,78 kN/cm²
f_{cd} =	f_{ck} / γ_c	=	20,00 kN/cm²
N_{sd} =	$\gamma_G * N_G + \gamma_Q * N_Q$	=	-198,00 kN
M_{sd} =	$\gamma_G * M_G + \gamma_Q * M_Q$	=	697,50 kNm
d =	h - nom_c - d_s / 2 / 10³ - a	=	0,691 m
z_{s1} =	d - h / 2	=	0,316 m
$M_{sd,s}$ =	ABS(M_{sd}) - $N_{sd} * z_{s1}$	=	760,07 kNm
$\mu_{Sd,s}$ =	MIN($M_{sd,s}$ / 10³ / (b * d² * f_{cd});0,31)	=	0,310
⇒ compressive reinforcement is necessary!			
ζ =	TAB("reinf/Ecmy"; ζ; $\mu=\mu_{Sd,s}$)	=	0,75
ε_{c2} =	TAB("reinf/Ecmy"; ε_{c2}; $\mu=\mu_{Sd,s}$)	=	$-3,50*10^{-3}$
ε_{s1} =	TAB("reinf/Ecmy"; ε_{s1}; $\mu=\mu_{Sd,s}$)	=	$2,33*10^{-3}$
lim_$M_{sd,s}$ =	$\mu_{Sd,s}$ * b * d² * f_{cd} * 10³	=	740,10 kNm
$\Delta M_{Sd,s}$ =	$M_{sd,s}$ - lim_$M_{sd,s}$	=	19,97 kNm
d_2 =	nom_c + d_{s2} / 2 / 10³ - a	=	0,031 m
z =	ζ * d	=	0,518 m

req_A_{s1} = 1 / f_{yd} * (lim_Msd,s / z + $\Delta M_{Sd,s}$ / (d - d_2) + N_{sd}) * 10 = 29,00 cm²

Provide five 28 mm bars

$A_{s,sel}$ = SEL("reinf/As"; Name; d_s = d_s; As≥req_A_{s1}) = 5 Ø 28

prov_A_s = TAB("reinf/As"; As; Name=$A_{s,sel}$) = 30,79 cm²

req_A_{s1} / prov_A_s = **<u>0,94 < 1</u>**

req_A_{s2} = 1 / f_{yd} * $\Delta M_{Sd,s}$ / (d - d_2) * 10 = 0,70 cm²

Provide two 12 mm bars

$A_{s,sel}$ = SEL("reinf/As"; Name; d_s = d_{s2}; As≥req_A_{s2}) = 2 Ø 12

prov_A_s = TAB("reinf/As"; As; Name=$A_{s,sel}$) = 2,26 cm²

req_A_{s2} / prov_A_s = **<u>0,31 < 1</u>**

Check tensile strain yield:

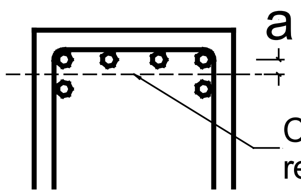
ε_{yd} = $2,17 \cdot 10^{-3}$

ε_{s2} = (ABS(ε_{c2}) + ε_{s1}) * (d - d_2) / d - ε_{s1} = $3,24 \cdot 10^{-3}$

ε_{s2} / ε_{yd} = **<u>1,49 > 1</u>**

⇒ Strain yield limit achieved!

Rectangular section with shearing and torsional forces:



System:

Support width a_1=	0,30 m
Beam width b=	0,40 m
Beam height h=	0,60 m
Slab thickness h_f=	0,50 m
nom_c=	0,04 m
Distance between centre of tension and lowest bar a =	0,011 m
From live load q_q=	9,41 kN/m
From dead load q_g=	20,20 kN/m
Support reaction V_G=	110,00 kN
Support reaction V_Q =	70,00 kN
Torsional moment T_{sd}=	30,00 kNm
Assumed corner of stirrup Θ =	40,00 °
Wall thickness of t_k=	0,10 m

Materials, stresses and partial safety factors:

Concrete =	SEL("concrete/EC"; Name;)	=	C12/15
Steel =	SEL("reinf/Steel"; Name;)	=	420 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	12,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	420 MN/m²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,20 N/mm²
minρ_w =	WENN(f_{ck}<250,00007;WENN(f_{ck}<40;0,0011;0,0013))	=	0,00110
d =	h-nom_c-a	=	0,549 m
f_{yd}=	f_{yk} / 1,15	=	365,22 N/mm²
f_{cd}=	f_{ck} / 1,5	=	8,00 N/mm²
γ_G=			1,35
γ_Q=			1,50

Shear Analysis:

max_V =	$V_G * \gamma_G + V_Q * \gamma_Q$	=	253,50 kN
x_v =	$a_1 / 2 + d$	=	0,70 m

Effective shearing force:

V_{sd} =	max_V - $(q_g * \gamma_G + q_q * \gamma_Q) * x_v$	=	224,53 kN
4 / 7 / (1 / TAN(Θ))		=	**<u>0,48 < 1</u>**
(1 / TAN(Θ)) / 7 / 4		=	**<u>0,04 < 1</u>**
v =	$0,7 - f_{ck} / 200$	=	0,640 > 0,5
v' =	0,7 * v	=	0,448 > 0,35

For flanged beams:

z_r =	$d - h_f / 2$	=	0,299 m

For other sections:

z_r = 0,9 * d = 0,494 m

V_{Rd2} = (v' * f_{cd} * b * z_r) / (1/TAN(Θ)+TAN(Θ)) * 10³ = 348,72 kN

V_{sd} / V_{Rd2} = **0,64 < 1**

req_$a_{sw,V}$ = 10 * V_{sd} / (z_r * f_{yd}) * (TAN(Θ)) = 10,44 cm²/m

Provide links of size 12 mm (double-shear)

d_s = SEL("reinf/AsArea"; ds;) = 12,00 mm

a_s = SEL("reinf/AsArea";Name;d_s=d_s;a_s≥req_$a_{sw,V}$/2) = Ø 12 / e = 12.5

prov_a_{sw}= 2 * TAB("reinf/AsArea"; as; Name=a_s) = 18,10 cm²/m

req_$a_{sw,V}$ / prov_a_{sw} = **0,58 < 1**

V_{sd} / (0,67 * V_{Rd2}) = **0,96 < 1**

Torsional analysis:

A = b * h = 0,240 m²

u = 2 * (b + h) = 2,00 m

(2 * nom_c) / t_k = 0,80 < 1

t_k / (A / u) = 0,83 < 1

b_k = b - t_k = 0,30 m

d_k = h - t_k = 0,50 m

A_k = b_k * d_k = 0,15 m²

T_{Rd1} = (2 * v' * f_{cd} * t_k * A_k)/(TAN(Θ)+(1/(TAN(Θ))))*10³ = 52,94 kNm

T_{sd} / T_{Rd1} = **0,57 < 1**

req_$a_{sw,T}$ = T_{sd} * 10 / (2 * A_k * f_{yd}) * TAN(Θ) = 2,30 cm²/m

ρ_w = req_$a_{sw,T}$ / 10^4 / t_k = 0,00230

minρ_w / ρ_w = **0,48 < 1**

a_{sl} = T_{sd} * 10 / (2 * A_k * f_{yd}) * (1 / (TAN(Θ))) = 3,26 cm²/m

ρ_l= a_{sl}/t_k/10000 = 0,00326

minρ_w/ρ_l = **0,34 < 1**

Shearing and torsional forces:

Shearing reinforcement will be allocated to both sides:

(T_{sd} / T_{Rd1})² + (V_{sd} / V_{Rd2})² = **0,74 < 1**

req_a_{sw} = req_$a_{sw,T}$ + req_$a_{sw,V}$ / 2 = **7,52 cm²/m**

Provide links of size 12 mm (double-shear)

d_s = SEL("reinf/AsArea"; ds;) = 12,00 mm

a_s = SEL("reinf/AsArea";Name;d_s=d_s;a_s≥req_$a_{sw,V}$/2) = Ø 12 / e = 12.5

prov_a_{sw}= 2*TAB("reinf/AsArea"; as; Name=a_s) = 18,10 cm²/m

req_a_{sw} / prov_a_{sw} = **0,42 < 1**

Shearing analysis for rectangular sections:

Section properties:

Support width a_1 =	0,30 m
Rib width b_w =	0,30 m
Slab thickness h_f =	0,15 m
Rib depth d =	0,385 m
Tension reinforcement req_A_{s1} =	13,23 cm²
Without the influence of longitudinal stress σ_{cp} =	0,00 N/mm²

Loads:

Uniform load q_q =	9,41 kN/m
Uniform load q_g =	20,20 kN/m
Support reaction V_G =	65,25 kN
Support reaction V_Q =	30,39 kN

Materials, stresses and partial safety factors:

Concrete =	SEL("concrete/EC"; Name;)	=	C20/25
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	20,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,24 N/mm²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	13,33 N/mm²
γ_G=			1,35
γ_Q=			1,50

Shear Analysis:

max_V =	$V_G * \gamma_G + V_Q * \gamma_Q$	=	133,67 kN
x_v =	$a_1 / 3 + d$	=	0,48 m
V_{sd} =	max_V - $(q_g * \gamma_G + q_q * \gamma_Q) * x_v$	=	113,81 kN
v =	0,7 - f_{ck} / 200	=	0,60 N/mm² > 0,5

For flanged beams:

z_r = d - h_f / 2 = 0,31 m

For other sections:

z_r = 0,9 * d = 0,35 m

Standard methods:

V_{Rd2} = 1 / 2 * v * f_{cd} * b_w * z_r * 10³ = 419,89 kN

V_{sd} / V_{Rd2} = **<u>0,27 < 1</u>**

k =	MAX(1,6 - d; 1)	=	1,22
φ_1 =	req_A_{s1} / (b_w * d * 10^4)	=	0,011 < 0,02

V_{Rd1} = $(\tau_{Rd} * k * (1{,}2 + 40 * \varphi_1) + 0{,}15 * \sigma_{cp}) * b_w * d * 10^3$ = 55,46 kN

req_a_{sw} = $(V_{sd} - V_{Rd1}) * 10 / (z_r * f_{yd})$ = 3,83 cm²/m

Provide links of size 8 mm (double-shear)

d_s = SEL("reinf/AsArea"; ds;) = 8,00 mm

a_s = SEL("reinf/AsArea";Name;d_s=d_s;a_s≥req_a_{sw}/2) = Ø 8 / e = 25

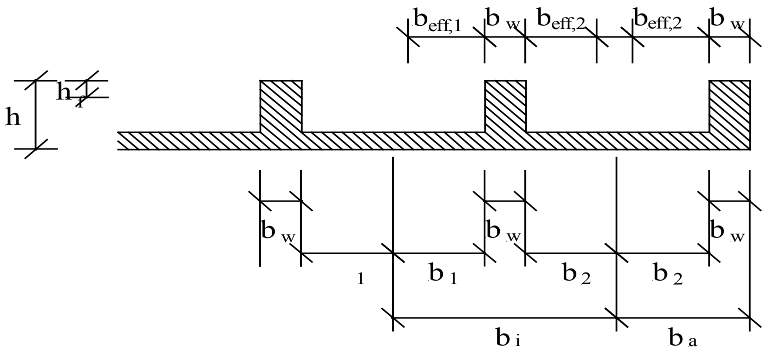
prov_a_{sw}= 2 * TAB("reinf/AsArea"; as; Name=a_s) = 4,02 cm²/m

req_a_{sw} / prov_a_{sw} = **0,95 < 1**

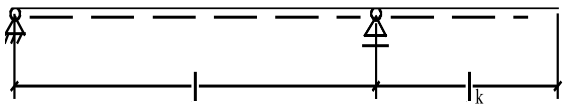
Flanged beams

Effective flange width of a cantilever beam:

Elevation:



Load diagram:



Section properties:

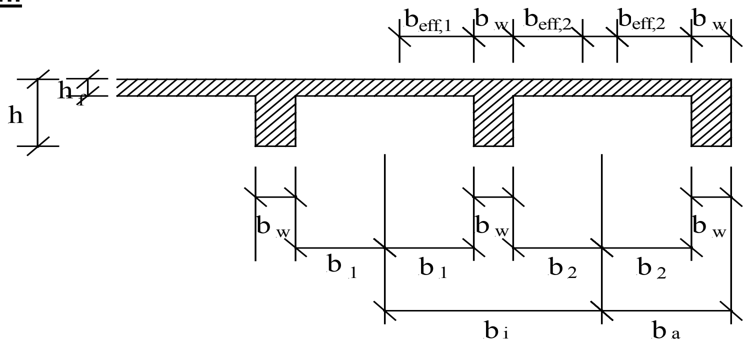
Span length l_1 =	6,26 m
Cantilever length l_c =	2,44 m
Support width a_1 =	0,30 m
Support width a_k =	0,30 m
Beam width b_w =	0,30 m
half slab width b_1 =	1,75 m
half slab width b_2 =	1,37 m

Cantilever beam, bottom flange:

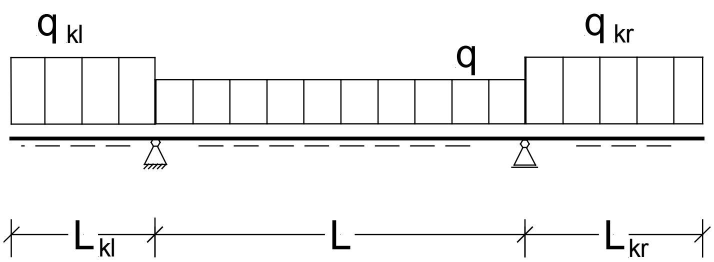
l_{eff} =	$l_c + a_k / 2$	=	2,59 m
l_0 =	$2{,}0 * l_c$	=	4,88 m
b_{eff} =	$MIN(b_w + l_0 / 5; b_w + b_1 + b_2)$	=	1,28 m

Effective flange width of a single-span beam with cantilevers:

Elevation:



Load diagram:



Section properties:

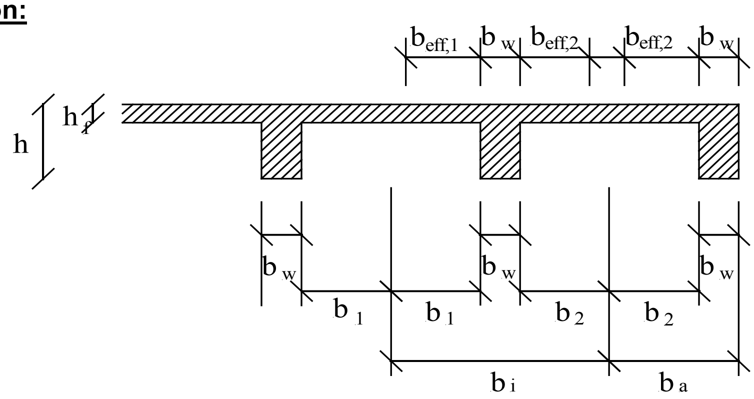
Span length l_1 =	6,26 m
Support width a_1 =	0,30 m
Support width a_2 =	0,30 m
Beam width b_w =	0,30 m
half slab width b_1 =	1,75 m
half slab width b_2 =	1,37 m

Single-span beam, top flange:

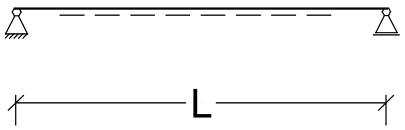
l_{eff1} =	$l_1 + a_1 / 2 + a_2 / 2$	=	6,56 m
l_0 =	$0,7 * l_{eff1}$	=	4,59 m
b_{eff} =	$MIN(b_w + l_0 / 5; b_w + b_1 + b_2)$	=	1,22 m

Eff. Flange width Single-span:

Elevation:



Load diagram:



Section properties:

Span length l_1 = 6,26 m
Support width a_1 = 0,30 m
Support width a_2 = 0,30 m
Beam width b_w = 0,30 m
half slab width b_1 = 1,75 m
half slab width b_2 = 1,37 m

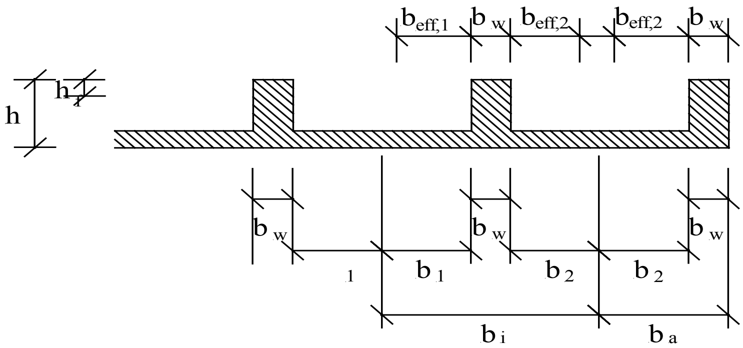
Single-span beam, top flange:

l_{eff1} = $l_1 + a_1 / 2 + a_2 / 2$ = 6,56 m
l_0 = l_{eff1} = 6,56 m

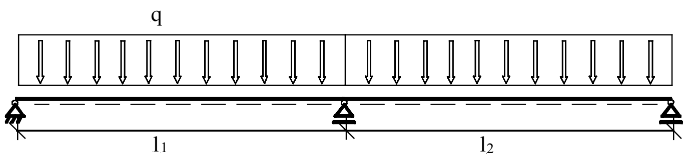
b_{eff} = $\mathrm{MIN}(b_w + l_0 / 5;\ b_w + b_1 + b_2)$ = 1,61 m

Eff. Flange width at an internal column:

Elevation:



Load diagram:



$l_2 \leq 1{,}5\ l_1$

Section properties:

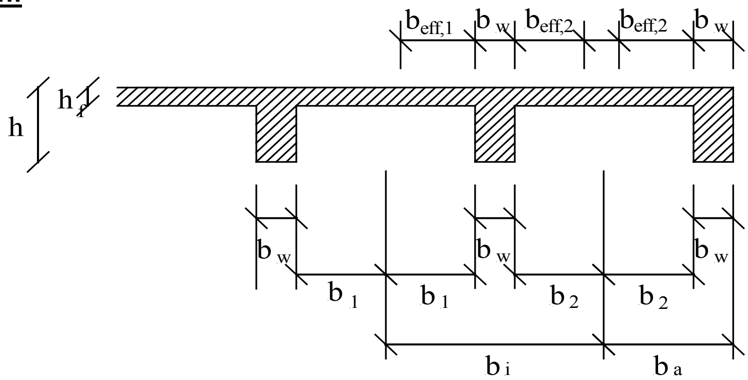
Span length l_1 =	5,73 m
Span length l_2 =	6,26 m
Support width a_1 =	0,30 m
Support width a_2 =	0,30 m
Support width a_3 =	0,30 m
Beam width b_w =	0,30 m
half slab width b_1 =	1,75 m
half slab width b_2 =	1,37 m

Continuous flanged beam, bottom flange:

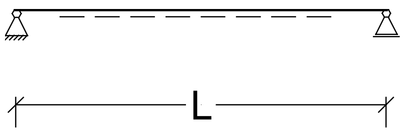
l_{eff1} =	$l_1 + a_1 / 3 + a_2 / 2$	=	5,98 m
l_{eff2} =	$l_2 + a_2 / 2 + a_3 / 3$	=	6,51 m
l_0 =	$0{,}15 * (l_{eff1} + l_{eff2})$	=	1,87 m
b_{eff} =	$\text{MIN}(b_w + l_0 / 5;\ b_w + b_1 + b_2)$	=	0,67 m

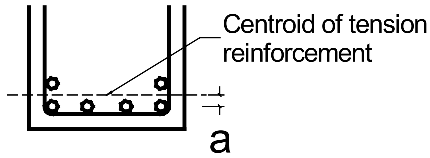
Effective flange width of a single-span beam:

Elevation:



Load diagram:





Section properties:

Span length l_1 = 6,26 m
Support width a_1 = 0,30 m
Support width a_2 = 0,30 m
Beam width b_w = 0,30 m
half slab width b_1 = 1,75 m
half slab width b_2 = 1,37 m
Tee beams height h = 0,45 m
Slab height h_f = 0,15 m
Axis of bending tension reinforcement a = 0,02 m
Assumed bar size d_{s1} = 0,025 m
nom_c = 0,035 m

Single-span beam, top flange:

l_{eff1} =	$l_1 + a_1 / 3 + a_2 / 3$	=	6,46 m
l_0 =	l_{eff1}	=	6,46 m
b_{eff} =	$MIN(b_w + l_0 / 5; b_w + b_1 + b_2)$	=	1,59 m
L =	l_{eff1}	=	6,46
b =	$b_1 + b_2 + b_w$	=	3,42 m

from dead load:	$(b * h_f + b_w * (h - h_f)) * 25$	=	15,07 kN/m
From dead floor load:	b * 1,50	=	5,13 kNm
		max q_g=	**20,20 kNm**

from live load:	b * 1,50	=	5,13 kN/m
from partition surcharge:	b * 1,25	=	4,28 kN/m
		max q_q=	**9,41 kN/m**

V_G =	q_g * L/2	=	65,25 kN
V_Q =	q_q * L/2	=	30,39 kN
M_G =	q_g* L² / 8	=	105,37 kNm
M_Q =	q_q* L² / 8	=	49,09 kNm

Bending design of retangular cross section:

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S

Partial safety factors:

γ_G = 1,35

γ_Q = 1,50

Design Calculation:

M_{sd} =	$\gamma_G * M_G + \gamma_Q * M_Q$	=	215,88 kNm
d =	$h - nom\_c - a - d_{s1} / 2$	=	0,383 m
z_{s1} =	d - h / 2	=	0,158 m
$M_{sd,s}$ =	$ABS(M_{sd})$	=	215,88 kNm
k_d =	$d * 100 / \sqrt{(M_{sd,s} / b_{eff})}$	=	3,29
k_s =	TAB("reinf/kd"; ks1; Name=Concrete; kd=k_d)	=	2,374
ζ =	TAB("reinf/kd"; ζ; Name=Concrete; kd=k_d)	=	0,969
ξ =	TAB("reinf/kd"; ξ; Name=Concrete; kd=k_d)	=	0,082
x =	ξ * d	=	0,031 m
z =	ζ * d	=	0,371 m
req_A_s=	$M_{sd,s}/(d*100)*k_s$	=	13,38 cm²

Provide three 25 mm bars

Bar size d_s=	SEL("reinf/As"; ds;)	=	25 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; $d_s = d_s$; As≥req_A_s)	=	4 Ø 25
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	19,63 cm²

req_A_s / prov_A_s = **0,68 ≤ 1**

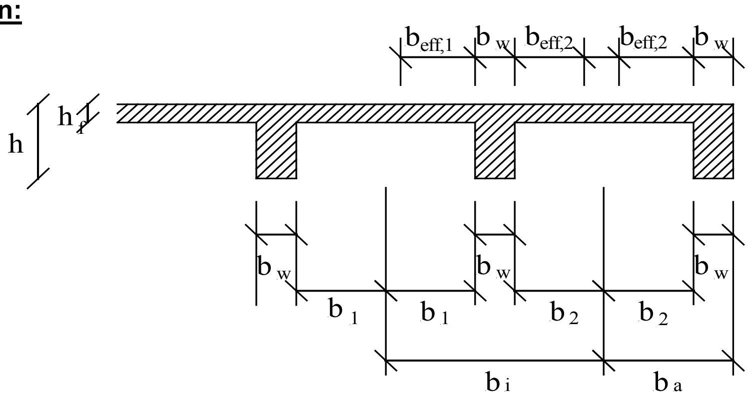
Whole compressed section is in flange:

x = ξ * d = 0,031 m

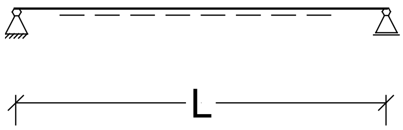
x / h_f = **0,21 < 1**

Single-span beam with shearing force:

Elevation:



Load diagram:



Section properties:

Span length l_1 =	6,26 m
Support width a_1 =	0,30 m
Support width a_2 =	0,30 m
Beam width b_w =	0,30 m
half slab width b_1 =	1,75 m
half slab width b_2 =	1,37 m
Slab thickness h =	0,45 m
Slab height h_f =	0,15 m
Axis of bending tension reinforcement a =	0,02 m
Assumed bar size d_{s1} =	0,025 m
nom_c =	0,035 m
without alons stress influence σ_{cp} =	0,00

Single-span beam, top flange:

l_{eff1} =	$l_1 + a_1 / 3 + a_2 / 3$	=	6,46 m
l_0 =	l_{eff1}	=	6,46 m
b_{eff} =	MIN($b_w + l_0 / 5$; $b_w + b_1 + b_2$)	=	1,59 m
L =	l_{eff1}	=	6,46 m
b =	$b_1 + b_2 + b_w$	=	3,42 m

Loads:

from dead load:	$(b * h_f + b_w * (h - h_f)) * 25$	=	15,07 kN/m
From dead floor load:	b * 1,50	=	5,13 kNm
		max q_g=	**20,20 kNm**
from live load:	b * 1,50	=	5,13 kN/m
from partition surcharge:	b * 1,25	=	4,28 kN/m

		max q_q=	**9,41 kN/m**
V_G =	q_g * L / 2	=	65,25 kN
V_Q =	q_q * L / 2	=	30,39 kN
M_G =	q_g * L² / 8	=	105,37 kNm
M_Q =	q_q * L² / 8	=	49,09 kNm

Bending design of retangular cross section:

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C20/25
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	20,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,24 N/mm²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	13,33 N/mm²

Partial safety factors:

γ_G =	1,35
γ_Q =	1,50

Design Calculation:

M_{sd} =	γ_G * M_G + γ_Q * M_Q	=	215,88 kNm
d =	h - nom_c - a - d_{s1} / 2	=	0,383 m
z_{s1} =	d - h / 2	=	0,16 m
$M_{sd,s}$ =	ABS(M_{sd})	=	215,88 kNm
k_d =	d * 100 / √($M_{sd,s}$ / b)	=	4,82
k_s =	TAB("reinf/kd"; ks1; Name=Concrete; kd=k_d)	=	2,357
ζ =	TAB("reinf/kd"; ζ; Name=Concrete; kd=k_d)	=	0,976
ξ =	TAB("reinf/kd"; ξ; Name=Concrete; kd=k_d)	=	0,065
ε_{c2} =	TAB("reinf/kd"; ε_{c2}; Name=Concrete; kd=k_d)	=	$-1,740*10^{-3}$
ε_{s1} =	TAB("reinf/kd"; ε_{s1}; Name=Concrete; kd=k_d)	=	$25,000*10^{-3}$
x =	ξ * d	=	0,025 m
z =	ζ * d	=	0,374 m
req_A_s=	$M_{sd,s}$/(d*100)*k_s	=	13,29 cm²

Provide three 25 mm bars

Bar size d_s=	SEL("reinf/As"; ds;)	=	25 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	3 Ø 25
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	14,73 cm²

req_A_s / prov_A_s = **0,90 ≤ 1**

Whole compressed section is in flange:

x / h_f = **0,17 < 1**

Shear Analysis:

max_V =	V_G * γ_G + V_Q * γ_Q	=	133,67 kN
x_v =	a_1 / 3 + d	=	0,48 m
V_{sd} =	max_V - (q_g * γ_G + q_q * γ_Q) * x_v	=	113,81 kN

$v =$ 0,7 - f_{ck} / 200 = 0,60 N/mm² > 0,5

For flanged beams:

$z_r =$ d - h_f / 2 = 0,31 m

For other sections:

$z_r =$ 0,9 * d = 0,34 m

Standard methods:

$V_{Rd2} =$ 1 / 2 * v * f_{cd} * b_w * z_r * 10³ = 407,90 kN

V_{sd} / V_{Rd2} = **0,28 < 1**

k = MAX(1,6 - d; 1) = 1,22

$\varphi_1 =$ req_A_s / (b_w * d * 10^4) = 0,012 < 0,02

$V_{Rd1} =$ (τ_{Rd} * k * (1,2 + 40 * φ_1) + 0,15 * σ_{cp}) * b_w * d * 10³ = 56,52 kN

req_a_{sw} = (V_{sd} - V_{Rd1}) * 10 / (z_r * f_{yd}) = 3,88 cm²/m

Provide links of siye 8 mm (double-shear)

d_s = SEL("reinf/AsArea"; ds;) = 8,00 mm

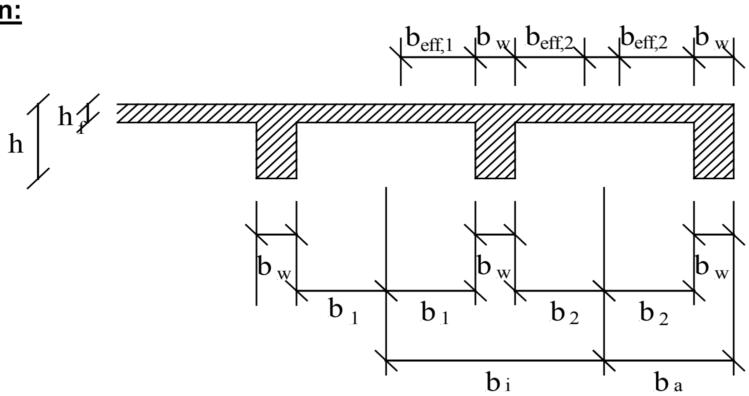
a_s = SEL("reinf/AsArea";Name;d_s=d_s;a_s≥req_a_{sw}/2) = ∅ 8 / e = 25

prov_a_{sw}= 2 * TAB("reinf/AsArea"; as; Name=a_s) = 4,02 cm²/m

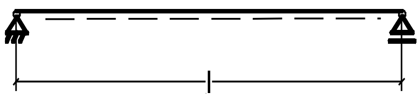
req_a_{sw} / prov_a_{sw} = **0,97 < 1**

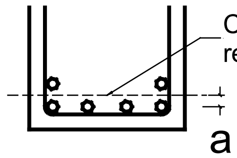
Single-span flanged beam:

Elevation:



Load diagram:





Section properties:

Span length l_1 =	6,26 m
Support width a_1 =	0,30 m
Support width a_2 =	0,30 m
Beam width b_w =	0,30 m
half slab width b_1 =	1,75 m
half slab width b_2 =	1,37 m
Slab thickness h =	0,45 m
Slab height h_f =	0,15 m
Axis of bending tension reinforcement a =	0,02 m
Assumed bar size d_{s1} =	0,025 m
nom_c =	0,035 m

Single-span beam, top flange:

l_{eff1} =	$l_1 + a_1 / 3 + a_2 / 3$	=	6,46 m
l_0 =	l_{eff1}	=	6,46 m
b_{eff} =	$MIN(b_w + l_0 / 5;\ b_w + b_1 + b_2)$	=	1,59 m
L =	l_{eff1}	=	6,46 m
b =	$b_1 + b_2 + b_w$	=	3,42 m

from dead load:	$(b * h_f + b_w * (h - h_f)) * 25$	=	15,07 kN/m
From dead floor load:	b * 1,50	=	5,13 kNm
		max q_g=	**20,20 kNm**

from live load:	b * 1,50	=	5,13 kN/m
from partition surcharge:	b * 1,25	=	4,28 kN/m
		max q_q=	**9,41 kN/m**

V_G =	q_g * L/2	=	65,25 kN
V_Q =	q_q * L/2	=	30,39 kN
M_G =	q_g* L² / 8	=	105,37 kNm
M_Q =	q_q* L² / 8	=	49,09 kNm

<u>Bending design of retangular cross section:</u>

Materials and stresses:

Concrete =	SEL("concrete/EC"; Name;)	=	C30/37
Steel =	SEL("reinf/Steel"; Name;)	=	500 S
f_{ck} =	TAB("concrete/EC"; fck; Name=Concrete)	=	30,00 N/mm²
f_{yk} =	TAB("reinf/Steel"; βs; Name=Steel)	=	500 MN/m²
τ_{Rd} =	TAB("concrete/EC"; τ_{Rd}; Name=Concrete)	=	0,28 N/mm²
f_{yd}=	f_{yk} / 1,15	=	434,78 N/mm²
f_{cd}=	f_{ck} / 1,5	=	20,00 N/mm²

Partial safety factors:

γ_G = 1,35

γ_Q = 1,50

Design Calculation:

M_{sd} =	$\gamma_G * M_G + \gamma_Q * M_Q$	=	215,88 kNm
d =	$h - nom\_c - a - d_{s1} / 2$	=	0,383 m
z_{s1} =	d - h / 2	=	0,16 m
$M_{sd,s}$ =	ABS(M_{sd})	=	215,88 kNm
$\mu_{Sd,s}$ =	$M_{sd,s} / 10^3 / (b * d^2 * f_{cd})$	=	0,022
ω =	TAB("reinf/Ecmy"; ω; μ=$\mu_{Sd,s}$)	=	0,022
ζ =	TAB("reinf/Ecmy"; ζ; μ=$\mu_{Sd,s}$)	=	0,980
ξ =	TAB("reinf/Ecmy"; ξ; μ=$\mu_{Sd,s}$)	=	0,056
req_A_s =	$(\omega * d * 10^4 * b * f_{cd}) / f_{yd}$	=	13,26 cm²

Provide three 25 mm bars

Bar size d_s=	SEL("reinf/As"; ds;)	=	25 mm
$A_{s,sel}$ =	SEL("reinf/As"; Name; d_s = d_s; As≥req_A_s)	=	4 Ø 25
prov_A_s =	TAB("reinf/As"; As; Name=$A_{s,sel}$)	=	19,63 cm²

req_A_s / prov_A_s = **<u>0,68 < 1</u>**

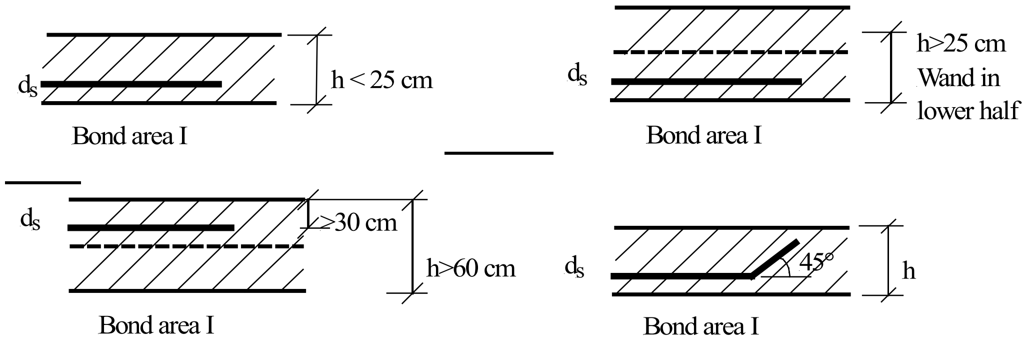
Whole compressed section is in flange:

x= ξ*d = 0,021 m

x/h_f = **<u>0,14 < 1</u>**

Reinforcement

General anchorage-bond length:



Section properties:

prov_A_s =	42,400 cm²		
req_A_s=	20,20 cm²		
Bar size d_s=	SEL("reinf/AsArea"; ds;)	=	25 mm
Concrete =	SEL("reinf/al"; Name;)	=	C35/45
Bonding depth Aa =	SEL("reinf/al"; AL;)	=	1
l_b =	TAB("reinf/al"; lb; AL=Aa; Name=Concrete; ds=d_s)	=	80,0 cm

$l_{b,min}$ =	MAX(10 * d_s; 100)	=	250,00 mm
α_A=			1,00 For staggerded tension rei
α_A=	req_A_s/prov_A_s	=	0,48
Typ =	SEL("reinf/ATyps"; Typ;)	=	straight bar at support end
α_a =	TAB("reinf/ATyps"; αa; Typ=Typ)	=	1,00
$l_{b,net1}$ =	α_A * α_a * l_b	=	38,400 m
$l_{b,net2}$ =	0,3 * l_b	=	24,000 m
$l_{b,net3}$ =	$l_{b,min}$ / 1000	=	0,250 m
$l_{b,net}$ =	MAX($l_{b,net1}$; $l_{b,net2}$; $l_{b,net3}$)	=	38,400 m

For restrained support ends:

$l'_{b,net}$ =	2 / 3 * $l_{b,net}$	=	25,600 m