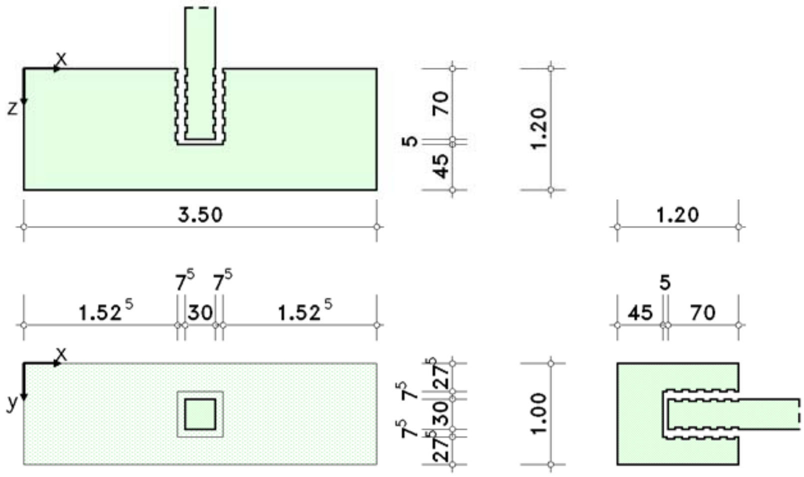
sleeve foundation

reinf. concr. design acc. to DIN EN 1992-1-1:2011-01 with NA-Deutschland(DIN EN 1992-1-1/NA:2013-04)

scale 1:75, profiling not to scale



foundation:	column:
concrete strength class C30/37	concrete strength class C35/45
steel class B500A	steel class B500A

1. soil situation

the anchoring depth of the foundation is t = 0.80 m.
the ground water level (below top edge soil) is at t_W = 1.00 m.

2. loading

2.1. Structure of action effects

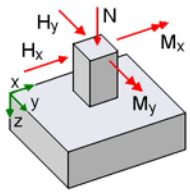
On the left-hand side, the action effects and load cases are shown in a tree structure. The right-hand side shows their characteristics of the superposition.

used symbols: action load case

1: permanent loads	**permanent loads**
└ 1: Ständig	additive
2: live loads	**other transient action effects**
└ 4: Nutzlast	additive
3: wind loads	**transient wind loads**
├ 7: wind +x-direction	alternative in group A
└ 8: wind -x-direction	alternative in group A
4: snowlast	**transient snow loads**
└ 9: snow	additive

2.2. Characteristic column load

point of application in column centroid auf top edge foundation slab



loadc.	N_{St} kN	$H_{x,St}$ kN	$H_{y,St}$ kN	$M_{x,St}$ kNm	$M_{y,St}$ kNm
1	200.00	0.00	0.00	0.00	0.00
4	100.00	0.00	0.00	0.00	55.00
7	0.00	36.00	0.00	0.00	-60.00
8	0.00	-36.00	0.00	0.00	60.00
9	80.00	0.00	0.00	0.00	50.00

2.3. Einschränkungen for die loadkombination

- mindestens **ein load case der führenden action muß ungünstig wirken.**
- Folgende loadfälle wirken **immer ungünstig: 1**

2.4. dead load

Das Gewicht der foundation slab wird with γ_E = 25.00 kN/m³ berücksichtigt.
no earth load in action.

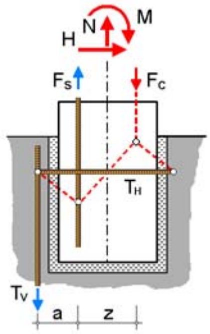
the resultant of dead load in the floor joint is $N_{0,deadl,k}$ = 105.00 kN.

Das dead load wird im load case 1 with berücksichtigt.

3. transmission of force from the column to the foundation

Design calculation with einem strut and tie model acc. to [1], section 11:
maximum column tensile force F_S = min $A_{s,St,tension} \cdot f_{yd,St}$
vertical tensile force from column tensile force F_S and reinf.offset $T_V = F_S \cdot z/(a+z)$
horizontal tensile force from column tens. force F_S and reinf.offset $T_h = T_V/\tan\theta$
vertical reinforcem. min $A_{s,v} = T_V/(f_{yd,K})$
horizontal reinforcem. min $A_{s,h} = T_h/(f_{yd,K})$

requirements: profiled lateral surfaces of column base
and interior surfaces of the sleeve acc. to figure 6.9 aus [2].



3.1. design values sleeve design

3.1.1. factorization of load case combinations

LK	design situat.	factorization
1	permanent and transient	1.35·Lf1+1.5·Lf4
2	permanent and transient	1.35·Lf1+1.5·Lf4+0.6·1.5·Lf7
3	permanent and transient	1.35·Lf1+1.5·Lf4+0.5·1.5·Lf9
4	permanent and transient	1.35·Lf1+1.5·Lf4+0.6·1.5·Lf7+0.5·1.5·Lf9
5	permanent and transient	1.35·Lf1+1.5·Lf4+0.6·1.5·Lf8
6	permanent and transient	1.35·Lf1+1.5·Lf4+0.6·1.5·Lf8+0.5·1.5·Lf9
7	permanent and transient	1.35·Lf1+1.5·Lf7
8	permanent and transient	1.35·Lf1+0.8·1.5·Lf4+1.5·Lf7
9	permanent and transient	1.35·Lf1+1.5·Lf7+0.5·1.5·Lf9
10	permanent and transient	1.35·Lf1+0.8·1.5·Lf4+1.5·Lf7+0.5·1.5·Lf9
11	permanent and transient	1.35·Lf1+1.5·Lf8
12	permanent and transient	1.35·Lf1+0.8·1.5·Lf4+1.5·Lf8
13	permanent and transient	1.35·Lf1+1.5·Lf8+0.5·1.5·Lf9
14	permanent and transient	1.35·Lf1+0.8·1.5·Lf4+1.5·Lf8+0.5·1.5·Lf9
15	permanent and transient	1.35·Lf1+1.5·Lf9
16	permanent and transient	1.35·Lf1+0.8·1.5·Lf4+1.5·Lf9
17	permanent and transient	1.35·Lf1+0.6·1.5·Lf7+1.5·Lf9
18	permanent and transient	1.35·Lf1+0.8·1.5·Lf4+0.6·1.5·Lf7+1.5·Lf9
19	permanent and transient	1.35·Lf1+0.6·1.5·Lf8+1.5·Lf9
20	permanent and transient	1.35·Lf1+0.8·1.5·Lf4+0.6·1.5·Lf8+1.5·Lf9

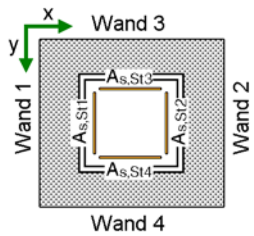
3.1.2. column load

increasing factor for flex. mom.: $\Delta M_{St,TH.II.O} = M_{St} \cdot$ **20%**
(for the consideration of increase of moments from non-linear effects)

LK	$N_{St,d}$ kN	$H_{x,St,d}$ kN	$H_{y,St,d}$ kN	$M_{x,St,d}$ kNm	$M_{y,St,d}$ kNm	LK	$N_{St,d}$ kN	$H_{x,St,d}$ kN	$H_{y,St,d}$ kN	$M_{x,St,d}$ kNm	$M_{y,St,d}$ kNm
1	420.00	0.00	0.00	0.00	99.00	11	270.00	-54.00	0.00	0.00	108.00
2	420.00	32.40	0.00	0.00	34.20	12	390.00	-54.00	0.00	0.00	187.20
3	480.00	0.00	0.00	0.00	144.00	13	330.00	-54.00	0.00	0.00	153.00
4	480.00	32.40	0.00	0.00	79.20	14	450.00	-54.00	0.00	0.00	232.20
5	420.00	-32.40	0.00	0.00	163.80	15	390.00	0.00	0.00	0.00	90.00
6	480.00	-32.40	0.00	0.00	208.80	16	510.00	0.00	0.00	0.00	169.20
7	270.00	54.00	0.00	0.00	-108.00	17	390.00	32.40	0.00	0.00	25.20
8	390.00	54.00	0.00	0.00	-28.80	18	510.00	32.40	0.00	0.00	104.40
9	330.00	54.00	0.00	0.00	-63.00	19	390.00	-32.40	0.00	0.00	154.80
10	450.00	54.00	0.00	0.00	16.20	20	510.00	-32.40	0.00	0.00	234.00

3.2. input values

edge distance column longit. reinf. $d_{1,St}$ = 5.0 cm
upper clearance thickness t_{Fx}/t_{Fy} = 7.5/7.5 cm
edge distance vert. sleeve reinf. $d_{1,K}$ = 4.0 cm
existing column longitudinal reinforcement
° face 1 and 2: $A_{s,St,1} = A_{s,St,2}$ = 25.1 cm²
° face 3 and 4: $A_{s,St,3} = A_{s,St,4}$ = 25.1 cm²
max. diameter of existing column longitudinal reinforcement d_s = Ø 10
assumption for lower concrete cover in column base $c_{nom,St,u}$ = 3.0 cm
assumption for upper concrete cover in the slab $c_{nom,F,o}$ = 3.5 cm
assumption for angle of compression strut in the clearance Θ = 45 °



3.3. Design calculation in x/z-plane

minimum column reinforcement

LK	$A_{s,St}$ (per side) cm²	$A_{s,St,comp.}$ cm²	$A_{s,St,tens.}$ cm²
1	6.0	6.0	6.0
2	-	-	-
3	10.8	10.8	10.8
4	3.2	3.2	3.2
5	13.6	13.6	13.6
6	18.3	18.3	18.3
7	8.5	-	8.5
8	-	-	-
9	2.7	-	2.7
10	-	-	-
11	8.5	8.5	8.5
12	16.6	16.6	16.6
13	13.2	13.2	13.2
14	21.3	21.3	21.3
15	5.2	5.2	5.2
16	13.4	13.4	13.4
17	-	-	-
18	5.9	5.9	5.9
19	12.8	12.8	12.8
20	20.9	20.9	20.9

$a = d_{1,St} + t_{F,x} + d_{1,K} = 16.5$ cm
$z = \max\{ 0.9\cdot(h_{St,x}-d_1); (h_{St,x}-2\cdot d_1) \} = 22.5$ cm

minimum sleeve reinforcement

LK	F_s kN	T_v kN	T_h kN	min $A_{s,h,K}$ cm²	min $A_{s,v,K}$ cm²
1	261.9	151.1	151.1	3.5	3.5
2	0.0	0.0	0.0	-	-
3	467.7	269.8	269.8	6.2	6.2
4	138.7	80.0	80.0	1.8	1.8
5	590.7	340.8	340.8	7.8	7.8
6	794.8	458.5	458.5	10.5	10.5
7	370.6	213.8	213.8	4.9	4.9
8	0.0	0.0	0.0	-	-
9	115.9	66.9	66.9	1.5	1.5
10	0.0	0.0	0.0	-	-
11	370.6	213.8	213.8	4.9	4.9
12	721.0	415.9	415.9	9.6	9.6
13	572.6	330.4	330.4	7.6	7.6
14	924.2	533.2	533.2	**12.3**	**12.3**
15	228.0	131.5	131.5	3.0	3.0
16	584.1	337.0	337.0	7.8	7.8
17	0.0	0.0	0.0	-	-
18	256.5	148.0	148.0	3.4	3.4
19	557.1	321.4	321.4	7.4	7.4
20	910.3	525.2	525.2	12.1	12.1

3.4. Design calculation in y/z-plane

no sleeve load in this direction.

3.5. selection of sleeve reinforcement

selected: **B500A**, vertical for face 1 and 2 jeweils
11 Ø 12 = 12.4 > 12.3 cm²
B500A, horizontal stirrups
6 double shear stirrups Ø 12 = 13.6 > 12.3 cm²

3.6. minimum anchoring depth

min $t = 1.5\cdot h_{St} = 45.0$ cm < 70.0 cm

3.7. anchorage of column longitudinal reinforcement

existing anchorage length exis $l_b = t - c_{nom,St,u} = 67.0$ cm

basic anchorage length

design value of steel stress (B500A, $\gamma_s = 1.15$) $f_{yd} = 434.78$ N/mm²
design value of bond stress f_{bd}:
- concrete parameters (C35/45) $f_{ctk;0.05} = 2.24$ N/mm², $\gamma_c = 1.50$
- good bond conditions
- increase der bond stress um 50%, da eine allseitige, reinforcement ensured all-round concrete cover > 10 d_s (this concrete cover is ensured by the poured joint)

$f_{bd} = 2.25\cdot f_{ctk;0.05}/\gamma_c\cdot 1.5 = 5.04$ N/mm²
basic anchorage length $l_b = (d_s/4)\cdot(f_{yd}/f_{bd}) = 21.6$ cm

anchorage as compression reinforcement

straight bar ends: $\alpha_a = 1.0$
unfavourable ratio of min $A_{s,compr.}$/exis $A_s = 0.85$
minimum value of anchorage length $l_{b,min} = \max\{ 0.6\cdot l_b, 10\cdot d_s \} = 12.9$ cm
minimum anchorage length $l_{b,net} = \max\{ \alpha_a\cdot l_b\cdot A_{s,min}/A_{s,exis}, l_{b,min} \} =$ **18.3** < 67.0 cm

anchorage as bending-tension reinforcement
straight bar ends: $\alpha_a = 1.0$
unfavourable ratio of min $A_{s,tens.}$/exis A_s = 0.85
minimum value of anchorage length $l_{b,min} = \max\{0.3 \cdot \alpha_a \cdot l_b,\ 10 \cdot d_s\} = 10.0$ cm
minimum anchorage length $l_{b,net} = \max\{\alpha_a \cdot l_b \cdot A_{s,min}/A_{s,exis},\ l_{b,min}\} =$ **18.3** < 67.0 cm

lap length of bending-tension reinforcement with vertical upstanding stirrup leg
existing lap length exis $l_b = t - c_{nom,St,u} - c_{nom,F,o} = 63.5$ cm
clear bar distance $a_n = a - (d_{s,St} + d_{s,K})/2. = 15.4$ cm
reduced anchorage length $l_{b,net} = \max\{(T_{v2}/F_s) \cdot l_{b,net},\ l_{b,min}\} = 10.5$ cm
coefficient for the lap lengths of a tensile joint with > 30: $\alpha_l = 1.4$
minimum value of lap length $l_{s,min} = \max\{0.3 \cdot \alpha_a \cdot \alpha_l \cdot l_b,\ 15 \cdot d_s,\ 200\text{ mm}\} = 20.0$ cm
minimum lap length $l_s = \max\{l_{b,net} \cdot \alpha_l,\ l_{s,min}\} + (a_n - 4 \cdot d_s) =$ **31.4** < 63.5 cm

3.8. anchorage of vertical stirrups

basic anchorage length
design value of steel stress (B500A, $\gamma_s = 1.15$) $f_{yd} = 434.78$ N/mm²
design value of bond stress f_{bd}:
- concrete parameters (C30/37) $f_{ctk;0.05} = 2.03$ N/mm², $\gamma_c = 1.50$
- good bond conditions
- increase der bond stress um 50%, da eine allseitige, reinforcement ensured all-round concrete cover > 10 d_s

$f_{bd} = 2.25 \cdot f_{ctk;0.05}/\gamma_c \cdot 1.5 = 4.57$ N/mm²
basic anchorage length $l_b = (d_s/4) \cdot (f_{yd}/f_{bd}) = 28.6$ cm

minimum anchorage length
unfavourable ratio of $A_{s,min}/A_{s,exis} = 0.99$
straight bar ends: $\alpha_a = 1.0$
minimum value of anchorage length $l_{b,min} = \max\{0.3 \cdot \alpha_a \cdot l_b,\ 10 \cdot d_s\} = 12.0$ cm
minimum anchorage length $l_{b,net} = \max\{\alpha_a \cdot l_b \cdot A_{s,min}/A_{s,exis},\ l_{b,min}\} =$ **28.2** cm

lap length with column longitudinal reinforcement
coefficient for the lap lengths of a tensile joint with > 30: $\alpha_l = 1.4$
minimum value of lap length $l_{s,min} = \max\{0.3 \cdot \alpha_a \cdot \alpha_l \cdot l_b,\ 15 \cdot d_s,\ 200\text{ mm}\} = 20.0$ cm
minimum lap length $l_s = \max\{l_{b,net} \cdot \alpha_l,\ l_{s,min}\} + (a_n - 4 \cdot d_s) =$ **50.0** < 63.5 cm

t_{Fx}/t_{Fy} - upper clearance thickness in the particular axis direction   t - column anchoring depth

4. design calculation of foundation slab

4.1. partial safety factors for material

design situat.	γ_c	γ_s
permanent and transient	1.50	1.15

4.2. design values of reinforced concrete design

Die Mobilisierung des passive earth pressurees wird vernachlässigt.

4.2.1. factorization of load case combinations

LK	design situat.	factorization
1	permanent and transient	1.35· Lf1+1.5· Lf4
2	permanent and transient	1.35· Lf1+1.5· Lf4+0.6· 1.5· Lf7
3	permanent and transient	1.35· Lf1+1.5· Lf4+0.5· 1.5· Lf9
4	permanent and transient	1.35· Lf1+1.5· Lf4+0.6· 1.5· Lf7+0.5· 1.5· Lf9
5	permanent and transient	1.35· Lf1+1.5· Lf4+0.6· 1.5· Lf8
6	permanent and transient	1.35· Lf1+1.5· Lf4+0.6· 1.5· Lf8+0.5· 1.5· Lf9
7	permanent and transient	1.35· Lf1+1.5· Lf7
8	permanent and transient	1.35· Lf1+0.8· 1.5· Lf4+1.5· Lf7
9	permanent and transient	1.35· Lf1+1.5· Lf7+0.5· 1.5· Lf9
10	permanent and transient	1.35· Lf1+0.8· 1.5· Lf4+1.5· Lf7+0.5· 1.5· Lf9
11	permanent and transient	1.35· Lf1+1.5· Lf8
12	permanent and transient	1.35· Lf1+0.8· 1.5· Lf4+1.5· Lf8
13	permanent and transient	1.35· Lf1+1.5· Lf8+0.5· 1.5· Lf9
14	permanent and transient	1.35· Lf1+0.8· 1.5· Lf4+1.5· Lf8+0.5· 1.5· Lf9
15	permanent and transient	1.35· Lf1+1.5· Lf9
16	permanent and transient	1.35· Lf1+0.8· 1.5· Lf4+1.5· Lf9
17	permanent and transient	1.35· Lf1+0.6· 1.5· Lf7+1.5· Lf9
18	permanent and transient	1.35· Lf1+0.8· 1.5· Lf4+0.6· 1.5· Lf7+1.5· Lf9
19	permanent and transient	1.35· Lf1+0.6· 1.5· Lf8+1.5· Lf9
20	permanent and transient	1.35· Lf1+0.8· 1.5· Lf4+0.6· 1.5· Lf8+1.5· Lf9

4.2.2. column load

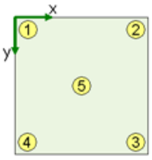
increasing factor for flex. mom.: $\Delta M_{St,TH.II.O} = M_{St} \cdot$ **20%**
(for the consideration of increase of moments from non-linear effects)

LK	$N_{St,d}$ kN	$H_{x,St,d}$ kN	$H_{y,St,d}$ kN	$M_{x,St,d}$ kNm	$M_{y,St,d}$ kNm
1	420.00	0.00	0.00	0.00	99.00
2	420.00	32.40	0.00	0.00	34.20
3	480.00	0.00	0.00	0.00	144.00
4	480.00	32.40	0.00	0.00	79.20
5	420.00	-32.40	0.00	0.00	163.80
6	480.00	-32.40	0.00	0.00	208.80
7	270.00	54.00	0.00	0.00	-108.00
8	390.00	54.00	0.00	0.00	-28.80

LK	$N_{St,d}$ kN	$H_{x,St,d}$ kN	$H_{y,St,d}$ kN	$M_{x,St,d}$ kNm	$M_{y,St,d}$ kNm
9	330.00	54.00	0.00	0.00	-63.00
10	450.00	54.00	0.00	0.00	16.20
11	270.00	-54.00	0.00	0.00	108.00
12	390.00	-54.00	0.00	0.00	187.20
13	330.00	-54.00	0.00	0.00	153.00
14	450.00	-54.00	0.00	0.00	232.20
15	390.00	0.00	0.00	0.00	90.00
16	510.00	0.00	0.00	0.00	169.20
17	390.00	32.40	0.00	0.00	25.20
18	510.00	32.40	0.00	0.00	104.40
19	390.00	-32.40	0.00	0.00	154.80
20	510.00	-32.40	0.00	0.00	234.00

4.3. base pressure

determination of base pressures assuming linear soil stresses and elimination of tension stress in the corner points: σ_1 to σ_4, stress in centroid: σ_5



LK	σ_1 kN/m²	σ_2 kN/m²	σ_3 kN/m²	σ_4 kN/m²	σ_5 kN/m²
1	208.99	112.01	112.01	208.99	160.50
2	158.21	162.79	162.79	158.21	160.50
3	248.17	107.11	107.11	248.17	177.64
4	197.39	157.89	157.89	197.39	177.64
5	259.77	61.23	61.23	259.77	160.50
6	298.96	56.33	56.33	298.96	177.64
7	33.01	202.28	202.28	33.01	117.64
8	106.08	197.77	197.77	106.08	151.93
9	72.19	197.38	197.38	72.19	134.79
10	145.27	192.88	192.88	145.27	169.07
11	202.28	33.01	33.01	202.28	117.64
12	275.36	28.50	28.50	275.36	151.93
13	241.46	28.11	28.11	241.46	134.79
14	314.54	23.60	23.60	314.54	169.07
15	196.01	107.85	107.85	196.01	151.93
16	269.09	103.34	103.34	269.09	186.21
17	145.23	158.63	158.63	145.23	151.93
18	218.31	154.12	154.12	218.31	186.21
19	246.79	57.06	57.06	246.79	151.93
20	319.87	52.56	52.56	**319.87**	186.21

4.4. Design calculation for bending

4.4.1. longitudinal reinforcement in x-direction

reinforcement edge distance top/bottom h_{so}/h_{su} = 7.0/7.0 cm

moments in design calculation sections

LK	x = 175.0 cm 1) kNm	x = 80.0 cm kNm	x = 270.0 cm kNm
1	217.50	51.55	25.25
2	170.32	37.78	39.02
3	264.00	63.02	24.76
4	212.16	49.24	38.53
5	269.34	65.33	11.47
6	315.84	76.79	10.98
7	194.38	1.73	47.64
8	202.78	23.22	48.09
9	195.88	13.19	47.15
10	204.28	34.69	47.60
11	194.40	47.64	1.73
12	282.00	69.14	2.18
13	240.90	59.11	1.24
14	328.50	80.60	1.69
15	201.00	47.61	23.70
16	288.60	69.11	24.15
17	162.82	33.84	37.47
18	236.76	55.33	37.92
19	252.84	61.39	9.93
20	**340.44**	82.88	10.38

1) rounded moment below column centre

Design calculation for LK 20: $\varepsilon_o/\varepsilon_u$ = -1.00/26.61‰ **min $A_{s,u}$ = 6.7 cm²**

4.4.2. longitudinal reinforcement in y-direction

reinforcement edge distance top/bottom h_{so}/h_{su} = 5.0/5.0 cm

moments in design calculation sections

LK	y = 50.0 cm 1) kNm
1	36.75
2	36.75
3	42.00
4	42.00
5	36.75
6	42.00
7	23.62
8	34.13
9	28.88
10	39.38
11	23.63
12	34.13
13	28.88
14	39.37
15	34.13
16	44.63
17	34.13
18	44.63
19	34.13
20	**44.63**

1) rounded moment below column centre

Design calculation for LK 20: $\varepsilon_o/\varepsilon_u$ = -0.17/26.09‰ **min $A_{s,u}$ = 0.8 cm²**

4.4.3. selected reinforcement in x-direction

top B500A, gleichmäßig zu verteilen
1 Ø 12 = 1.1 cm^2 (non-structurally reinforced)

bottom B500A, gleichmäßig zu verteilen
20 Ø 12 = 22.6 > 6.7 cm^2

4.4.4. selected reinforcement in y-direction

bottom B500A, gleichmäßig zu verteilen
6 Ø 12 = 6.8 > 0.8 cm^2

$\varepsilon_o/\varepsilon_u$ - strains in extreme fibres (top/bottom)

4.5. punching shear calculation

4.5.1. action within the basic control perimeter

$v_{Ed,crit} = \beta \cdot V_{Ed,red} / (u_{crit} \cdot d)$
$V_{Ed,red} = V_{Ed} - \Delta V_{Ed}$
$\Delta V_{Ed} = A_{crit} (\sigma_{Ed,gd,m} - g_{Ed,slab})$
$\beta = 1 + k \cdot M_{Ed} / V_{Ed} \cdot u_{crit} / W_{crit} \geq 1.10$
$W_{crit} = \int |e|\, dl$ mit dl: differential of perimeter
e: distance of dl to axis of M_{Ed}

coefficient for the calculation of shear stresses from moment action
(acc. to [2], table 6.1)
$c_1 = c_2 = 0.3 \Rightarrow k_x = k_y = 0.6$

calculated values of basic control perimeter

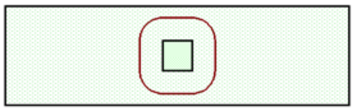
LK	a_{crit} cm	a/d -	u_{crit} m	A_{crit} m^2	$W_{crit,y}$ m^2
1	25.1	0.22	2.78	0.589	0.7735
2	29.1	0.25	3.03	0.704	0.9214
3	23.9	0.21	2.70	0.557	0.7335
4	26.8	0.23	2.88	0.637	0.8353
5	23.4	0.20	2.67	0.542	0.7139
6	23.4	0.20	2.67	0.542	0.7139
7	23.4	0.20	2.67	0.542	0.7139
8	29.1	0.25	3.03	0.704	0.9214
9	26.2	0.23	2.85	0.621	0.8144
10	31.9	0.28	3.21	0.793	1.0349
11	23.4	0.20	2.67	0.542	0.7139
12	23.4	0.20	2.67	0.542	0.7139
13	23.4	0.20	2.67	0.542	0.7139
14	23.4	0.20	2.67	0.542	0.7139
15	25.1	0.22	2.78	0.589	0.7735
16	23.4	0.20	2.67	0.542	0.7139
17	29.6	0.26	3.06	0.722	0.9436
18	25.6	0.22	2.81	0.604	0.7938
19	23.4	0.20	2.67	0.542	0.7139
20	23.4	0.20	2.67	0.542	0.7139

decisive shear stress within the basic control perimeter

LK	V_{Ed} kN	$\sigma_{Ed,gd,m}$ kN/m^2	ΔV_{Ed} kN	$M_{Ed,y,Sp}$ kNm	β -	$v_{Ed,crit}$ N/mm^2
1	420.00	120.09	70.68	-99.00	1.51	0.166
2	420.00	120.09	84.58	-34.20	1.16	0.113
3	480.00	137.25	76.49	-144.00	1.66	0.218
4	480.00	137.24	87.42	-79.20	1.34	0.160
5	420.00	120.10	65.09	-163.80	1.87	0.219
6	480.00	137.25	74.39	-208.80	1.98	0.263
7	270.00	77.21	41.85	108.00	1.90	0.142
8	390.00	111.51	78.54	28.80	1.15	0.103
9	330.00	94.36	58.56	63.00	1.40	0.117
10	450.00	128.66	102.04	-16.20	1.10	0.105
11	270.00	77.21	41.85	-108.00	1.90	0.142
12	390.00	111.52	60.45	-187.20	2.08	0.225
13	330.00	94.37	51.15	-153.00	2.04	0.187
14	450.00	128.67	69.74	-232.20	2.16	0.270
15	390.00	111.52	65.64	-90.00	1.50	0.153
16	510.00	145.83	79.04	-169.20	1.74	0.247
17	390.00	111.51	80.47	-25.20	1.13	0.100
18	510.00	145.82	88.15	-104.40	1.44	0.189
19	390.00	111.52	60.45	-154.80	1.89	0.205
20	510.00	145.83	79.04	-234.00	2.03	0.287

ΔV_{Ed} - resultant of ground pressure $M_{Ed,x,Sp}/M_{Ed,y,Sp}$ - moments concerning centre of control perimeter
β - load increase factor from eccentric load $v_{Ed,crit}$ - decisive shear stress within the basic control perimeter

4.5.2. Punching shear resistance within the basic control perimeter



$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_{l,tension} \cdot f_{ck})^{1/3} \cdot 2 \cdot d/a \geq v_{min} \cdot 2 \cdot d/a$ [N/mm²]
$C_{Rd,c} = 0.15/\gamma_C$
$k = 1 + \text{sqrt}(200/d) \leq 2.0$ with d [mm]
$\rho_{l,tension,max}$ = minimum from $(0.02, 0.5 \cdot f_{cd}/f_{yd})$
$\rho_{l,tension} = \text{sqrt}(\rho_{lx,tension} \cdot \rho_{ly,tension}) \leq \rho_{l,tension,max}$
$v_{min} = 0.0375/\gamma_C \cdot k^{3/2} \cdot f_{ck}^{1/2}$ for $d \geq 800$ mm

mean effective depth
$d_m = (113 + 115)/2 = 114$ cm

scale factor
$k = 1 + \text{sqrt}(200/1140) = 1.42 < 2$

longitudinal reinf. ratio of the anchored tension reinf.
mean of the tension reinforcement to the distance 3d from the column
$a_{s,x,3d} = 22.6/1 = 22.62$ cm²/m
$a_{s,y,3d} = 6.8/3.5 = 1.94$ cm²/m
$\rho_{lx,tension} = 22.62/113 \cdot 10^{-2} = 0.002$
$\rho_{ly,tension} = 1.94/115 \cdot 10^{-2} = 0.00017$
$\rho_{l,tension} = \text{sqrt}(0.002 \cdot 0.00017) = 0.00058$

punching shear resistance without shear reinforcement
$C_{Rd,c} = 0.15/1.5 = 0.1$
$\rho_{l,tension,max}$ = minimum from $(0.02, 0.5 \cdot 17/434.78) = 0.0195 > 0.0006$
$v_{min} \cdot 2 \cdot d/a = 0.0375/1.5 \cdot 1.42^{3/2} \cdot 30^{0.5} \cdot 2 \cdot 114/23.4 = 2.258$ N/mm²
$v_{Rd,c} = 0.1 \cdot 1.42 \cdot (100 \cdot 0.00058 \cdot 30)^{1/3} \cdot 2 \cdot 114/23.4 = 1.666$ N/mm² < 2.258 N/mm² $\Rightarrow v_{Rd,c} = 2.258$ N/mm²

0.287 N/mm² < 2.258 N/mm² ⇒ no additional reinforcement required

4.6. punching shear calculation im Bauzustand

design value der loading: $V_{Ed,Montage} = 100.00$ kN

4.6.1. action within the basic control perimeter

$v_{Ed,crit} = \beta \cdot V_{Ed}/(u_1 \cdot d)$
$\beta = 1 + k \cdot M_{Ed} / V_{Ed} \cdot u_1 / W_1 \geq 1.10$
$W_1 = \int |e|\, dl$ mit dl: differential of perimeter
e : distance of dl to axis of M_{Ed}

distance and length of the basic control perimeter
$a_{r,1} = 2 \cdot d = 78$ cm $\Rightarrow u_1 = 6.1$ m

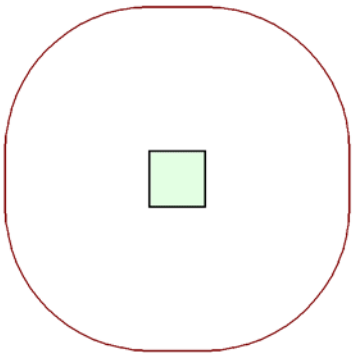
load increase factor at centric load
$\beta = \beta_{min} = 1.1$

decisive shear stress within the basic control perimeter

LK	V_{Ed} kN	β -	$v_{Ed,crit}$ N/mm²
1	100.00	1.10	**0.046**

$M_{Ed,x,Sp}/M_{Ed,y,Sp}$ - moments concerning centre of control perimeter   β - load increase factor from eccentric load
$v_{Ed,crit}$ - decisive shear stress within the basic control perimeter

4.6.2. Punching shear resistance within the basic control perimeter



$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_{l,tension} \cdot f_{ck})^{1/3} \geq v_{min}$ [N/mm²]
$C_{Rd,c} = 0.18/\gamma_C \cdot (0.1 \cdot u_0/d + 0.6) \geq 0.15/\gamma_C$
$k = 1 + \text{sqrt}(200/d) \leq 2.0$ with d [mm]
$\rho_{l,tension,max}$ = minimum from $(0.02, 0.5 \cdot f_{cd}/f_{yd})$
$\rho_{l,tension} = \text{sqrt}(\rho_{lx,tension} \cdot \rho_{ly,tension}) \leq \rho_{l,tension,max}$
$v_{min} = 0.0525/\gamma_C \cdot k^{3/2} \cdot f_{ck}^{1/2}$ for $d \leq 600$ mm

mean effective depth
$d_m = (38 + 40)/2 = 39$ cm

scale factor
$k = 1 + \text{sqrt}(200/390) = 1.72 < 2$

longitudinal reinf. ratio of the anchored tension reinf.
mean of the tension reinforcement to the distance 3d from the column
$a_{s,x,3d} = 22.6/1 = 22.62$ cm²/m
$a_{s,y,3d} = 5.1/2.64 = 1.94$ cm²/m
$\rho_{lx,tension} = 22.62/38 \cdot 10^{-2} = 0.00595$
$\rho_{ly,tension} = 1.94/40 \cdot 10^{-2} = 0.00049$
$\rho_{l,tension} = \text{sqrt}(0.00595 \cdot 0.00049) = 0.0017$

punching shear resistance without shear reinforcement
$u_0/d = 1.2/0.39 = 3.08 < 4$
$C_{Rd,c} = 0.18/1.5 \cdot (0.1 \cdot 3.08 + 0.6) = 0.109 > 0.15/1.5$
$\rho_{l,tension,max}$ = minimum from $(0.02, 0.5 \cdot 17/434.78) = 0.0195 > 0.0017$
$v_{min} = 0.0525/1.5 \cdot 1.72^{3/2} \cdot 30^{0.5} = 0.431$ N/mm²
$v_{Rd,c} = 0.109 \cdot 1.72 \cdot (100 \cdot 0.0017 \cdot 30)^{1/3} = 0.322$ N/mm² < 0.431 N/mm² $\Rightarrow v_{Rd,c} = 0.431$ N/mm²

0.046 N/mm² < 0.431 N/mm² ⇒ no additional reinforcement required

4.6.3. minimum reinforcement zur Vermeidung eines fortschreitenden failures

acc. to [3] clause 9.4.1 (3),NCI
min $A_s = V_{Ed,1.0} / f_{y,k}$

Anteil der lowern Feldbewehrung, der im Bereich der load distribution durchzuführen ist:

$V_{Ed,1.0} \approx 100.00/1.4 = 71.43$ kN
min A_s = $0.071 \cdot 10^4/500$ = **1.43 cm²**

5. summary

all executed verifications and design calculations successful.

longitudinal reinforcement x-direction	longitudinal reinforcement y-direction
min $A_{s,x}$ = 6.7 cm²	min $A_{s,y}$ = 0.8 cm²

Literatur and Normen:

[1] Deutscher Betonverein: Beispiele zur Bemessung nach DIN 1045-1, Band 1, Ernst & Sohn, 3.Aufl. 2009
[2] DIN EN 1992-1-1: Eurocode 2: Bemessung und Konstruktion von Stahlbeton- und Spannbetontragwerken, Teil 1-1, Januar 2011
[3] DIN EN 1992-1-1/NA: Nationaler Anhang - National festgelegte Parameter - Eurocode 2, part 1-1, April 2013