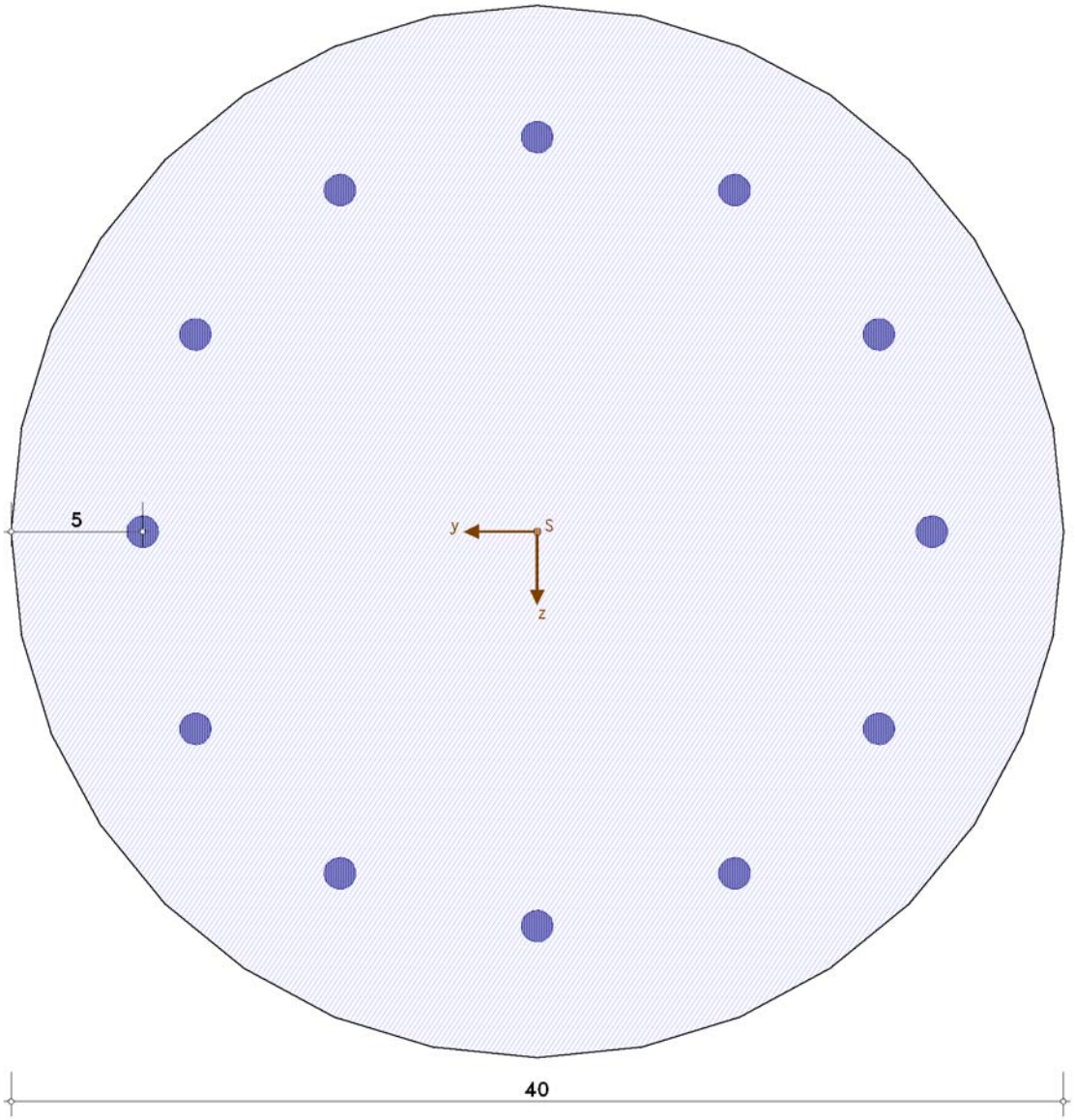
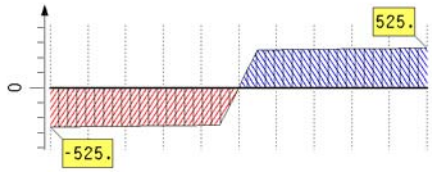
reinforced concrete design EC 2 (1.11), NA: Deutschland 4H-EC2QB Version: 10/2023-1b

1. input protocol



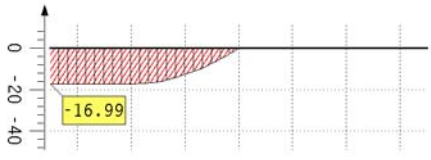
1.1. building material

reinforcing steel B500A, concrete C30/37
stress-strain line of reinforcing steel: EC 2-1-1, 3.2.7 (bilinear)



σ in N/mm²
ε in ‰
max ε = 25.00
max σ = 525.00

stress-strain line of concrete: EC 2-1-1, 3.1.7 (parabola-rectangle diagram)



σ in N/mm²
ε in ‰
min ε = -3.50
min σ = -16.99

1.2. material safety factors

design situation: basic combination
design resistance: concrete γ_c = 1.50, reinforcement γ_s = 1.15

1.3. cross section

circle: r = 20.0 cm, center distance: d_a = 5.0 cm
base reinforcement: A_{sa0} = 12 Ø 12 = 13.57 cm²
max. reinforcement ratio ρ_s = 8.00%

1.4. durability and concrete cover

internal: minimum strength class, concrete cover for $Ø_s$ = 8 mm
due to reinforcement corrosion X0 ⇒ C12/15, c_{min} = 10 mm, Δc = 10 mm, $c_{nom} = c_{min}+\Delta c$ = 20 mm
minimum concrete quality C12/15 with f_{ck} = 12.0 N/mm² < 30.0 N/mm² ok
minimum axial spacing min d = $c_{nom}+Ø_s/2$ = 24 mm < clc d = 30 mm ok
external: minimum strength class, concrete cover for $Ø_s$ = 12 mm
due to reinforcement corrosion X0 ⇒ C12/15, $c_{min} = Ø_s$ = 12 mm, Δc = 10 mm, $c_{nom} = c_{min}+\Delta c$ = 22 mm
minimum concrete quality C12/15 with f_{ck} = 12.0 N/mm² < 30.0 N/mm² ok
minimum axial spacing min d = $c_{nom}+Ø_s/2$ = 28 mm < clc d = 50 mm ok

1.5. design parameters

1.5.1. bending/shear design

1.5.1.1. bending design

minimum reinforcement for columns
tension reinforcement only, do not consider base reinforcement statically
minimum center of compression normal force

1.5.1.2. shear design

reinforcing steel like flexural reinforcemant
shear force
angle of the shear force reinforcement α = 90°
simplified approach of the compression strut angle
with minimum reinforcement (beam)
inner lever arm from bending design z ≤ d-2·$c_{v,l}$ ≤ d-$c_{v,l}$-3 cm
with concrete cover to longitudinal reinforcement in the compress. zone $c_{v,l}$ = 3.0 cm
limit the design value of the shear force resistance without shear force reinforcement $V_{Rd,c}$
effectiveness factor for circle design α_k = 0.800

1.5.1.3. design calculation values

lc	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	
1	-742.03	39.43	-9.86	-174.55	-38.24	Import lc 1
2	-96.56	-270.04	52.51	24.01	6.00	Import lc 2
3	-691.63	34.01	-8.50	-266.32	-57.58	Import lc 3
4	-655.63	39.43	-9.86	-29.08	-7.27	Import lc 4
5	-240.56	-270.04	52.51	-218.45	-45.61	Import lc 5
6	-218.99	15.83	-3.96	-8.68	-2.17	Import lc 6
7	-668.58	-132.09	24.02	-154.94	-33.33	Import lc 7
8	-534.56	-255.29	48.82	-232.62	-49.16	Import lc 8
9	-253.63	19.26	-4.81	-9.69	-2.42	Import lc 9

1.5.2. fire design

fire design with Gl.(5.7), EC 2-1-2
fire resistance class R 90
replacement length of the column in case of fire $l_{0,fi}$ = 4.2 m
conversion factor of internal forces from th.I.o. to th.II.o. f^{I-II} = 0.70

1.5.2.1. design calculation values

lc	N_{Ed} kN	$M_{y,Ed}$ kNm	$M_{z,Ed}$ kNm	
1	-317.69	11.29	43.73	Import lc 1
2	-181.37	-32.84	53.87	Import lc 2
3	-288.89	8.89	13.71	Import lc 3

lc	N_{Ed} kN	$M_{y,Ed}$ kNm	$M_{z,Ed}$ kNm	
4	-200.57	-32.84	21.54	Import lc 4
5	-197.69	5.27	49.51	Import lc 5
6	-272.57	-29.23	18.07	Import lc 6

2. bending/shear design

material properties

bending design:
concrete acc. to EC 2, 3.1.7(1): C30/37, ε_{c2} = -2.00‰, ε_{cu2} = -3.50‰, f_{cd} = 17.00 N/mm²
reinf. external acc. to EC 2, 3.2.7(2a): B500A, ε_{ud} = 25.0‰, f_{yd} = 434.78 N/mm², f_{td} = 456.52 N/mm², E_s = 200000.0 N/mm²
minimum reinforcement:

σ-ε line acc. to EC 2, 3.2.7(2b): B500A, f_{yk} = 500.0 N/mm², E_s = 200000.0 N/mm²
shear design:
σ-ε line acc. to EC 2, 3.2.7(2a): B500A, ε_{ud} = 25.00‰, f_{yd} = 434.78 N/mm², f_{td} = 456.52 N/mm², E_s = 200000.0 N/mm²

2.1. results table

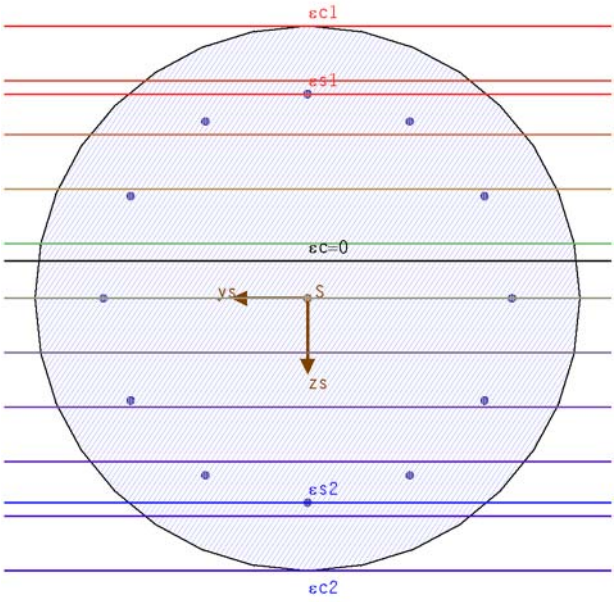
lc	N_{Ed} kN	M_{Ed} kNm	V_{Ed} kN	A_{sa} cm²	a_{sbV} cm²/m	
1	-742.03	178.95	39.49	26.52	3.71	
2	-96.56	271.11	52.85	55.14	3.71	
3	-691.63	268.48	58.20	51.09	3.71	
4	-655.63	48.99	12.25	2.26	3.71	min reinf.
5	-240.56	347.34	69.55	73.74	3.71	
6	-218.99	18.05	4.52	0.76	3.71	min reinf.
7	-668.58	203.60	41.08	33.40	3.71	
8	-534.56	345.38	69.28	72.18	3.71	
9	-253.63	21.56	5.38	0.88	3.71	min reinf.

N,M,V: design calculation values; A_{sa}: flexural reinforcement; a_{sbV}: shear reinforcement

2.2. lc 5 (decisive)

2.2.1. bending design (EC 2, 6.1)

bending/normal force
design calculation values: N_{Ed} = -240.56 kN, M_{Ed} = 347.34 kNm
design aid values: d = 30.4 cm, z = 24.4 cm, x = 17.25 cm
reinforcement
A_{sa} = 73.74 cm²
limit strains



limit strains: ε_{c1} = -3.500‰, ε_{s1} = -2.485‰, ε_{s2} = 3.600‰, ε_{c2} = 4.615‰, α_k = 90.00°

2.2.2. shear design (EC 2, 6.2)

shear force (EC 2, 6.2)
design shear force V_{Ed} = 69.55 kN
design aid values: ρ_l = 2.00%, z' = 24.4 cm, x = 17.25 cm, $V_{Rd,c}$ = 114.15 kN, Θ = 39.81°, $V_{Rd,max}$ = 612.01 kN,
AB = 1 for $V_{Ed}/V_{Rd,max}$ = 0.114, $\Delta F_{s,Ed}$ = 41.73 kN
reinforcement
a_{sbv} = 3.71 cm²/m
messages for calculation run
shear design: cross section compressed
shear design: longitudinal reinforcement considered

2.3. result

resulting reinforcement:	A_{sa} = 73.74 cm²
	a_{sbV} = 3.71 cm²/m
incl. base reinforcement:	A_{sa} = 73.74 cm²
	a_{sbV} = 3.71 cm²/m

3. fire design

material properties

concrete acc. to EC 2, 3.1.7(1): C30/37, ε_{c2} = -2.00‰, ε_{cu2} = -3.50‰, f_{cd} = 20.00 N/mm²
reinf. external acc. to EC 2, 3.2.7(2a): B500A, ε_{ud} = 25.0‰, f_{yd} = 434.78 N/mm², f_{td} = 456.52 N/mm², E_s = 200000.0 N/mm²

3.1. results table

initial reinforcement: $A_{sa,0}$ = 13.57 cm²

lc	N_{Ed} kN	M_{Ed} kNm	A_{sa} cm²	ΔA_{sa} cm²	μ_{fi}	$\mu_{fi,mx}$
1	-317.69	45.16	13.57	---	0.000	0.490
2	-181.37	63.09	13.57	---	0.000	0.490
3	-288.89	16.34	13.57	---	0.000	0.490
4	-200.57	39.27	13.57	---	0.000	0.490
5	-197.69	49.79	13.57	---	0.000	0.490
6	-272.57	34.36	13.57	---	0.000	0.490

N,M: design calculation values; A_{sa}: flexural reinforcement; ΔA_{sa}: additional reinforcement; μ_{fi},$\mu_{fi,mx}$: existing,maximum utilization

3.2. lc 1 (decisive)

design calculation values: N_{Ed} = -317.69 kN, M_{Ed} = 45.16 kNm
reinforcement
A_{sa} = 13.57 cm²
fire protection verification for compression members
goal: fire resistance class R 90 ($\mu_{fi,max} = \mu_{fi}^{f^{-II}} = 0.700^{0.70} = 0.490$)
utilization: μ_{fi} = 0.000 < $\mu_{fi,max}$ = 0.490 ok
Feuerwiderstandsdauer (EC 2-1-2, 5.3.2(4), Gl. (5.7)):
Kreis: Ø = 400 mm, d_1 = 50 mm, $l_{0,fi}$ = 4.20 m, A_s = 1357 mm², μ_{fi} = 0.000
Voraussetzungen: $d_1 \geq 25$ mm, $l_{0,fi} \leq 6$ m, 200 mm ≤ b' ≤ 450 mm, $A_s \leq 0.04 \cdot A_c$, $\mu_{fi} \leq 1$
A_c = 125664 mm², b' = Ø = 400 mm
$\omega = (A_s \cdot f_{yd})/(A_c \cdot f_{cd}) = 0.276$ with f_{yd} = 434.8 N/mm², f_{cd} = 17.00 N/mm²
$R_{\eta,fi} = 83 \cdot (1-\mu_{fi} \cdot (1+\omega)/((0.85/\alpha_{cc})+\omega)) = 82.98$, α_{cc} = 0.85
$R_a = 1.6 \cdot (d_1-30) = 32.00$, $R_l = 9.6 \cdot (5-l_{0,fi}) = 7.68$, $R_b = 0.09 \cdot b' = 36.00$, R_n = 12 for n > 4 Stäbe
Feuerwiderstandsdauer $R = 120 \cdot ((R_{\eta,fi}+R_a+R_l+R_b+R_n)/120)^{1.8}$ = 226 min
⇒ fire resistance class R 180
maximale fire resistance class R 180 > R 90 ok

3.3. result

resulting reinforcement: A_{sa} = 13.57 cm²
incl. base reinforcement: A_{sa} = 13.57 cm²

4. final result

maximum reinforcement: A_{sa} = 73.74 cm²
a_{sbV} = 3.71 cm²/m

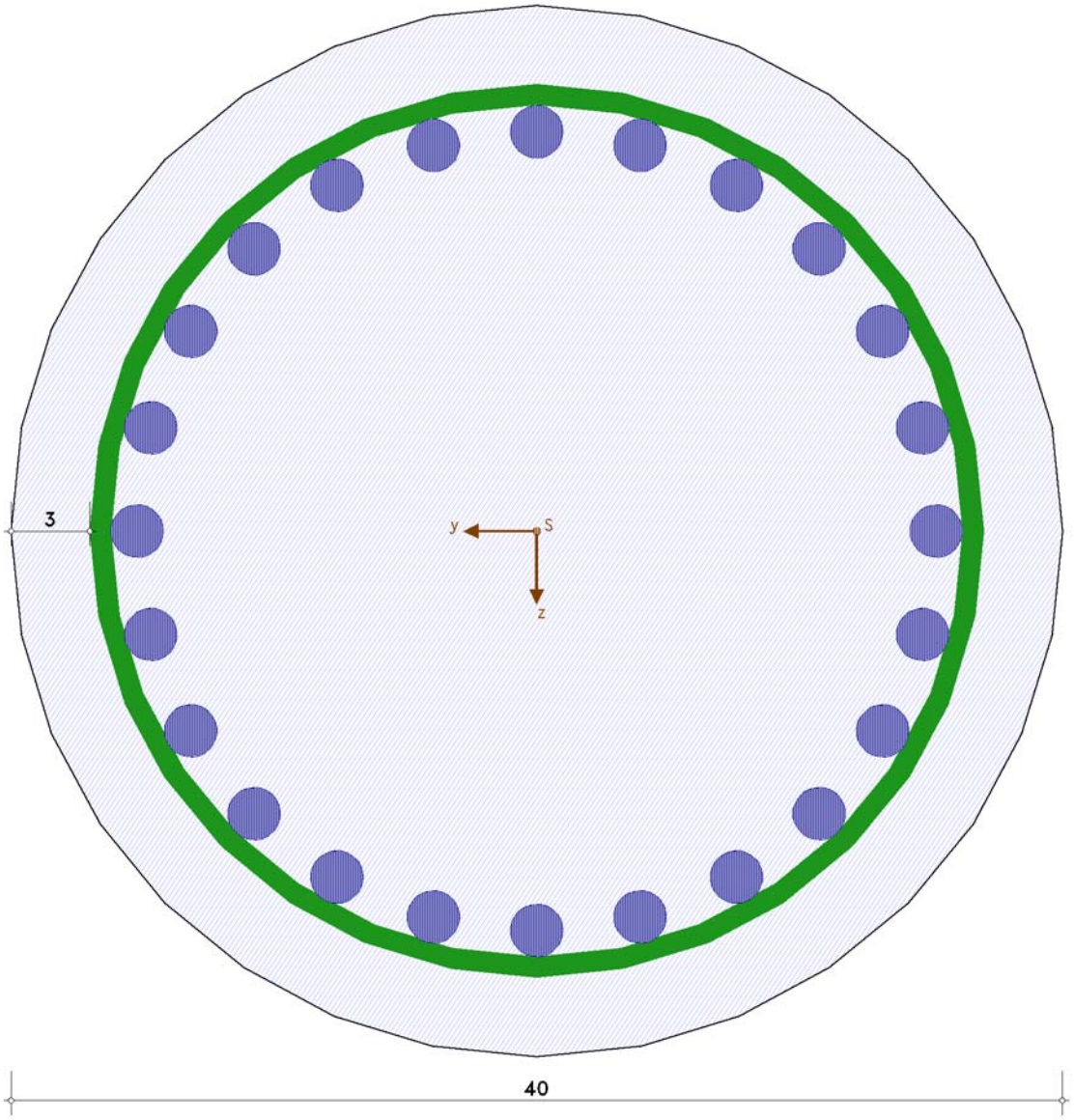
design resistance ensured

5. selected reinforcement

lateral concrete cover c_{vr} = 2.0 cm
bottom:
concrete cover c_{va} = 3.0 cm
longitudinal reinforcement from bending and normal force 24 x Ø20
reinforcement exst A_{sa} = 75.40 cm² > req A_{sa} = 73.74 cm² ok
bar distance min d_{va} = 4.0 cm
center distance exst d_a = 4.8 cm < d_a = 5.00 cm² ok
above:
concrete cover c_{vi} = 2.0 cm

shear reinforcement:
stirrup reinforcement from shear force Ø8 / 25.0 cm, 2-cut
reinforcement exst a_{sbV} = 4.02 cm²/m > req a_{sbV} = 3.71 cm²/m ok

graphic:



6. regulations

EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
EN 1990/NA, Nationaler Anhang zur EN 1990, Ausgabe Dezember 2010

EN 1992-1-1, Eurocode 2: Bemessung und Konstruktion von Stahlbeton- und Spannbetonbauteilen -
Teil 1-1: Allgemeine Bemessungsregeln und Regeln for den Hochbau;
Deutsche Fassung EN 1992-1-1:2004 + AC:2010, Ausgabe Januar 2011
EN 1992-1-1/NA, Nationaler Anhang zur EN 1992-1-1, Ausgabe April 2013