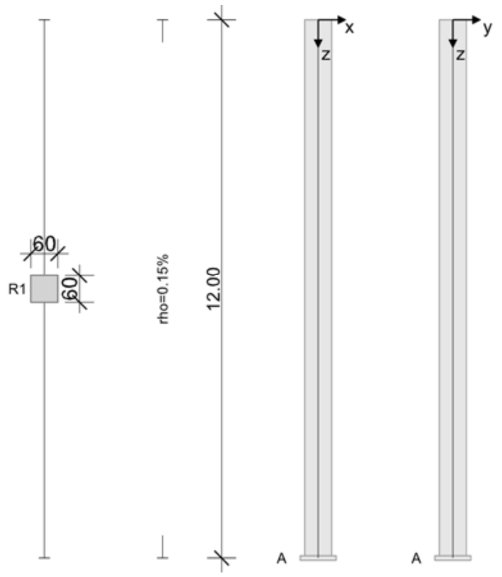
Project information

Contract	Müller/Giese
Description	Beispiel aus Brandschutz
Position	
Structural member	

System information



Standard:	DIN 1045-1:2008/2

Calculation principles

Geometrically and physically non-linear internal force calculation in the ultimate limit state due to structure deformations including creep deformations and pre-deformations acc. to 5.8.6.The design is carried out for the 1.00-fold non-linear internal forces.

For a reinforcement ratio up to 2% the effective bending stiffness in the calculation of req.A_s is assumed as E.cm * I_{brutto} * (0.2+15 A_s/Ac) at the most. The effective cross-section values calculated from the strain condition are, however, used without the previous limitation in the calculation of the final deformations.
This counteracts the risk of an intense drop of the bending stiffness of weakly reinforced cross-sections in condition 1→2.

Material characteristic of concrete under normal temperature for req.EI acc. to figure 3.2 and eq. 3.14, for design acc. to figure 3.3 and eq.3.17/3.18, reinforcement always acc. to figure 3.8.

Column geometry and reinforcement

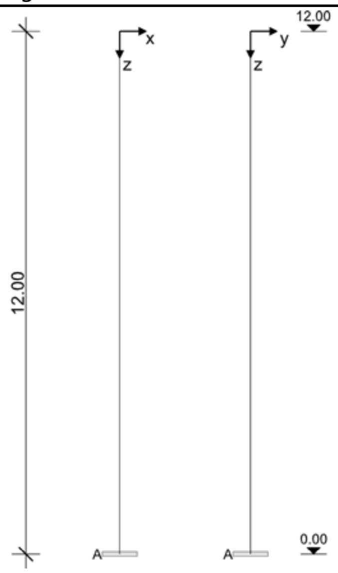
Cross-section	Type	b_x [m]	b_y [m]	A_c [m²]	d_1 [cm]	ρ_{max} [%]	Shape	Flame application
R1	Rectan.	0.600	0.600	0.36000	5.9	6.00	Corner reinf. 4x1	4

Section	Length [m]	Cross-section	e_x [cm]	e_y [cm]	ρ [%]	As [cm²]	$\varnothing_{exis.}$	Elements	Increments
1	12.00	R1	0.0	0.0	0.15	5.40	-	8	

Support states and imperfection

Elastic values proportional to the force and in the opposite direction to the displacement, C positive
automatic: determined by the program - thereby the direction of the pre-deformation is calculated by the ratio of the buckling stability and the load deformations according to 1st order theory

Final state "Lagerung 1"



Support	Height [m]	c_x [kN/m]	φ_y [kNm]	c_y [kN/m]	φ_x [kNm]
A	0.00	rigid	rigid	rigid	rigid

Imperfection			Direction vector	
Gradient	Height [m]	e_v [cm]	v_x	v_y
affine to the buckling figure	automatic	automatic	automatic	automatic

Material coefficients under normal temperature (C30/37, B500S)

f_{ck}	Cylinder compressive strength, concrete	f_{cd}	Concrete compressive strength, design value
f_{yk}	Reinforcing steel strength	f_{yd}	Reinforcing steel strength, design value
$\gamma_{c,perm}$, $\gamma_{c,außer}$	Partial safety factor, concrete, perm./accid.	$\gamma_{s,perm}$, $\gamma_{s,außer}$	Partial safety factor, reinforce., perm./accid.
α_{cc}	Creep strength coefficient, concrete	E_{c0m}	Tangent E-Modulus concrete
γ_c, γ_s	Unit weight concrete/reinforcement	E_s	E-Modulus reinforcement

Concrete	f_{ck} [N/mm²]	E_{c0m} [N/mm²]	$\gamma_{c,perm}$	$\gamma_{c,accid.}$	α_{cc}	f_{cd} [N/mm²]	γ_c [kN/m³]
C30/37	30.00	31939	1.50	1.30	0.85	17.00	25.00

Reinforcement	f_{yk} [N/mm²]	E_s [N/mm²]	$\gamma_{s,perm}$	$\gamma_{s,accid.}$	Ductility	f_{yd} [N/mm²]	γ_s [kN/m³]
B500S	500.00	200000	1.15	1.00	B (high)	434.78	78.50

Material characteristics under normal temperature

The name 'quadr' labels the center of a section with a square distribution.

Material	Analysis	Situation	σ−ε Values of the stress-strain-curve								
Concrete	Deformation	permanent	ε [‰]	-5.00	-2.20	quadr	-1.40	quadr	-0.60	quadr	0.00
			σ[N/mm²]	-25.3	-25.3	-24.4	-21.6	-17.2	-11.4	-6.0	0.0
Concrete	Design	permanent	ε [‰]	-5.00	-2.00	quadr	0.00				
			σ[N/mm²]	-17.0	-17.0	-12.8	0.0				
Concrete	ServiceSt.	permanent	ε [‰]	-10.00	0.00						
			σ[N/mm²]	-283.0	0.0						
Reinforcing steel	Design	permanent	ε [‰]	-11.00	-2.17	0.00	2.17	11.00			
			σ[N/mm²]	-434.8	-434.8	0.0	434.8	434.8			
Reinforcing steel	ServiceSt.	permanent	ε [‰]	-10.00	0.00	10.00					
			σ[N/mm²]	-2000.0	0.0	2000.0					

Fire protection

The analysis of the structural fire protection is carried out according to the simplified calculation method in EN 1992-1-2 of the extended zone method.The material characteristics for high temperature loading as well as the cross-sections are applied temperature-dependent reduced corresponding to the thermal analysis.The calculation is carried out non-linear analogical to the cold design under consideration of the thermal strain.Thermal curvatures are automatically not considered.

Thermal analysis

Fire resistance period	R 90	Moisture, concrete	0.00 Wgt-%
Hot gas temperature acc. to ETK	1006 °C	Conductivity	1.95 W/m K
Concrete aggregate	Quartzite	Specific heat	900 J/kgK
Manufacturing of reinforcing steel	cold-formed	Bulk density	2300 kg/m³
Flame application	4-lateral	Emission coefficient	0.70
Insulating plaster	0.00 cm	Leading coefficient	0.943 10e-6 m²/s

Zone	Reinforcement			mean temperatures [°C]		Thermal strain [‰]		damaged zone width
n	Shape	e [cm]	d1 [cm]	Concrete	Steel	Concrete	Steel	a_z [cm]
30	4x3	2.0	5.9	100	386	0.743	4.991	3.730

Material under high temperature

Concrete	$k_c(T)$	$f_{ck}(T)$	$E_{c,rm}(T)$	γ_c	α_{cc}	$f_{cd}(T)$
C30/37	1.00	30.0	28300	1.00	1.00	

Reinforcing steel	$k_{sy}(T)$	$f_{yk}(T)$	$E_S(T)$	γ_s	$k_{sp}(T)$	$f_{yp}(T)$
B500S	0.95	474.1	116385	1.00	0.65	327.3

Material characteristics under high temperature

The name 'quadr' labels the center of a section with a square distribution.

Material	Analysis	Situation	σ–ε Values of the stress-strain-curve								
Concrete	Fire	acciden.	ε [‰]	-22.50	-4.00	quadr	-2.67	quadr	-1.33	quadr	0.00
			σ[N/mm²]	0.0	-30.0	-30.0	-30.0	-21.2	-14.7	-7.5	0.0
Reinforcing steel	Fire	acciden.	ε [‰]	-199.66	-19.66	quadr	-2.47	0.00	2.20	quadr	20.34
			σ[N/mm²]	-474.1	-474.1	-452.9	-327.3	0.0	216.0	444.6	474.1
Reinforcing steel	Fire	acciden.	ε [‰]	200.34							
			σ[N/mm²]	474.1							

Loading

Load cases

Creep: 1 = 100%, 0 = 0% considered

LC	Type of action	Creep	γ_{sup}	γ_{inf}	ψ_0	ψ_1	ψ_2	Name
0	Dead load							
1	Permanent load	0.00	1.35	1.00	1.00	1.00	1.00	
2	Snow	0.00	1.50	0.00	0.50	0.20	0.00	

P_z	vertical single load	$e_{x/y}$	Eccentricity of the vertical single load
$P_{x/y}$	Horizontal forces	$p_{x/y/z\ a/e}$	Ordinate at the beginning/end of the line load in x/y/z-direction
$M_{x/y}$	Single moment about the x/y-axis	h_a	Height of the lower application point of the line load
h	Height of the application point of the single load	Length	Length of the line load
T	Load transfer from different calculation		

Dead load: p_z [kN/m] = 25.0 * A_{gross} for all LCC

LC	T	Single loads	h [m]	P_z [kN]	e_x [m]	e_y [m]	M_x [kNm]	M_y [kNm]	P_x [kN]	P_y [kN]
1			12.00	725.00	0.060					
2			12.00	125.00	0.060				5.00	

Load case combinations

LCC	Load case combination number	GK	Basic combination
Support	LCC is active in the support state i	AK	Impact (accidental)
Type	Type of combination	LS	Safety against displacement
Fire	Use LCC additionally for the tabular fire protection	EK	Earthquake combination
relev.	'*' The load case combination is relevant in the analyses	BK	Fire combination
φ_t	Creep coefficient φ_t	CR	Creep under sustained loading load case with φ_t

LCC	relev.	Type	φ_t	Support	Fire	Combination
1		GK		Lagerung 1	-	1.35*LC1
2		GK		Lagerung 1	-	1.35*LC1+1.50*LC2
3	*	BK		Lagerung 1	yes	1.00*LC1+0.20*LC2

Results

Only the results for the decisive design combination are being issued.

x_{vor}, y_{vor}	Displacements in x or y direction from pre-deformation
x_{ges}, y_{ges}	Total displacements in x and y direction
N_{Ed}, V_{Edx}, V_{Edy}, M_{Edx}, M_{Edy}	Stress resultants, 2nd order theory
N_{REd}, M_{Rdx}, M_{Rdy}	Bearable internal forces, associated with the strain level ε_1 - ε_2
beta	Angle β between x-axis and direction of the neutral axis
Utilization	existing internal forces / bearable internal forces (cross-section load bearing capacity)
A_s/A_c(*)	For combination type BK (fire): reinforcement amount relating to $A_{c,fire}$

1st order theory

Stress resultants acc. to 1st order theory

The calculation is carried out for each LCC with the gross cross-section values.

LCC	Height	Deformations				Stress resultants				
	[m]	x [mm]	y [mm]	φ_x [rad/1000]	φ_y [rad/1000]	N_{Ed} [kN]	M_{Edx} [kNm]	M_{Edy} [kNm]	V_{Edx} [kN]	V_{Edy} [kN]
3	12.00	12.49	0.00	0.00	-2.00	-750.0	0.0	45.0	-1.0	0.0
3	10.50	9.65	0.00	0.00	-1.78	-763.5	0.0	46.5	-1.0	0.0
3	9.00	7.16	0.00	0.00	-1.55	-777.0	0.0	48.0	-1.0	0.0
3	7.50	5.02	0.00	0.00	-1.31	-790.5	0.0	49.5	-1.0	0.0
3	6.00	3.24	0.00	0.00	-1.06	-804.0	0.0	51.0	-1.0	0.0
3	4.50	1.84	0.00	0.00	-0.81	-817.5	0.0	52.5	-1.0	0.0
3	3.00	0.82	0.00	0.00	-0.54	-831.0	0.0	54.0	-1.0	0.0
3	1.50	0.21	0.00	0.00	-0.28	-844.5	0.0	55.5	-1.0	0.0
3	0.00	0.00	0.00	0.00	0.00	-858.0	0.0	57.0	-1.0	0.0

Minimum reinforcement design (1st order theory)

The design is carried out with the stress resultants of the LCC acc. to 1st order theory: $A_{s.min} \geq A_s = 0.15 \cdot N_{Ed}/f_{yd}$ or $A_s = 0.0015 \cdot A$

LCC	Height	Load bearing capacity R_d			Strains					
	[m]	N_{Rd} [kN]	M_{Rdx} [kNm]	M_{Rdy} [kNm]	ε_1 [‰]	ε_2 [‰]	ε_s [‰]	Beta [°]	Utilization	A_s/A_c [%]
3	12.00	-7372.0	0.0	221.0	-2.57	-1.24	-1.37	90.0	0.102	0.15
3	10.50	-7372.0	0.0	221.0	-2.57	-1.24	-1.37	90.0	0.104	0.15
3	9.00	-7372.0	0.0	221.0	-2.57	-1.24	-1.37	90.0	0.105	0.15
3	7.50	-7372.0	0.0	221.0	-2.57	-1.24	-1.37	90.0	0.107	0.15
3	6.00	-7372.0	0.0	221.0	-2.57	-1.24	-1.37	90.0	0.109	0.15
3	4.50	-7372.0	0.0	221.0	-2.57	-1.24	-1.37	90.0	0.111	0.15
3	3.00	-7372.0	0.0	221.0	-2.57	-1.24	-1.37	90.0	0.113	0.15
3	1.50	-7372.0	0.0	221.0	-2.57	-1.24	-1.37	90.0	0.115	0.15
3	0.00	-7372.0	0.0	221.0	-2.57	-1.24	-1.37	90.0	0.116	0.15

2nd order theory (Load bearing capacity analysis)

Support forces (2nd order theory)

LCC	Height [m]	Support	A_{Edx} [kN]	A_{Edy} [kN]	A_{Edz} [kN]	M_{Edx} [kNm]	M_{Edy} [kNm]
1	0.00	A	0.0	0.0	1124.6	0.0	-122.1
2	0.00	A	7.5	0.0	1312.1	0.0	-282.5
3	0.00	A	1.0	0.0	858.0	0.0	-148.6

Effective stiffnesses (2nd order theory)

LCC	Height	Resistance R_d			Strains ULS				effective stiffnesses	
	[m]	N_{Rd} [kN]	M_{Rdx} [kNm]	M_{Rdy} [kNm]	ε_1 [‰]	ε_2 [‰]	ε_s [‰]	Beta [°]	$B_{x,eff}/B_x$	$B_{y,eff}/B_y$
3	12.00	-7278	0	437	-3.17	-0.83	-0.93	90.0	0.810	0.810
3	10.50	-6872	0	577	-3.69	-0.31	-0.45	90.0	0.809	0.809
3	9.00	-6413	0	681	-4.00	0.10	-0.07	90.0	0.808	0.808
3	7.50	-5902	0	744	-4.00	0.44	0.25	90.0	0.395	0.395
3	6.00	-5501	0	787	-4.00	0.74	0.54	90.0	0.385	0.385
3	4.50	-5205	0	815	-4.00	0.98	0.78	90.0	0.374	0.374
3	3.00	-5006	0	832	-4.00	1.16	0.94	90.0	0.365	0.365
3	1.50	-4897	0	842	-4.00	1.26	1.04	90.0	0.360	0.360
3	0.00	-4873	0	844	-4.00	1.28	1.06	90.0	0.359	0.359

Displacements and stress resultants acc. to 2nd order theory

LCC	Height	Displacements				Stress resultants					
	[m]	x_{vor} [mm]	y_{vor} [mm]	x_{ges} [mm]	y_{ges} [mm]	N_{Ed} [kN]	M_{Edx} [kNm]	M_{Edy} [kNm]	V_{Edx} [kN]	V_{Edy} [kN]	M^{II}/M^{I}
3	12.00	34.64	0.00	116.05	0.00	-750	0	45	-1	0	1.00
3	10.50	28.20	0.00	92.76	0.00	-764	0	64	-1	0	1.38
3	9.00	21.86	0.00	70.77	0.00	-777	0	83	-1	0	1.72
3	7.50	15.86	0.00	50.84	0.00	-791	0	100	-1	0	2.01
3	6.00	10.53	0.00	33.54	0.00	-804	0	115	-1	0	2.25
3	4.50	6.10	0.00	19.34	0.00	-818	0	128	-1	0	2.44
3	3.00	2.77	0.00	8.76	0.00	-831	0	138	-1	0	2.56
3	1.50	0.70	0.00	2.22	0.00	-845	0	145	-1	0	2.62
3	0.00	0.00	0.00	0.00	0.00	-858	0	149	-1	0	2.61

Load bearing capacity design (2nd order theory)

LCC		Height	Load bearing resistance R_d			Strains					
No	Type	[m]	N_{Rd} [kN]	M_{Rdx} [kNm]	M_{Rdy} [kNm]	ε_1 [‰]	ε_2 [‰]	ε_s [‰]	Beta [°]	Utilization	A_s/A_c(*) [%]
3	BK	12.00	-7278	0	437	-3.17	-0.83	-0.93	90.0	0.103	2.34
3	BK	10.50	-6872	0	577	-3.69	-0.31	-0.45	90.0	0.111	2.34
3	BK	9.00	-6413	0	681	-4.00	0.10	-0.07	90.0	0.121	2.34
3	BK	7.50	-5902	0	744	-4.00	0.44	0.25	90.0	0.134	2.34
3	BK	6.00	-5501	0	787	-4.00	0.74	0.54	90.0	0.146	2.34
3	BK	4.50	-5205	0	815	-4.00	0.98	0.78	90.0	0.157	2.34
3	BK	3.00	-5006	0	832	-4.00	1.16	0.94	90.0	0.166	2.34
3	BK	1.50	-4897	0	842	-4.00	1.26	1.04	90.0	0.172	2.34

3	BK	0.00	-4873	0	844	-4.00	1.28	1.06	90.0	0.176	2.34

Strain analysis (Serviceability limit state) (2nd order theory)

LCC	Height	Resistance R_d			Strains SLS					
	[m]	N_{Rd} [kN]	M_{Rdx} [kNm]	M_{Rdy} [kNm]	ε_1 [‰]	ε_2 [‰]	Beta [°]	$\sigma_{s,freq}$ [N/mm²]	A_{ct}/A_c	ρ_L [%]
3	12.00	-750	0	45	-0.10	-0.03	90.0	-6.0	0.000	0.000
3	10.50	-764	0	46	-0.10	-0.03	90.0	-6.0	0.000	0.000
3	9.00	-777	0	48	-0.11	-0.03	90.0	-6.0	0.000	0.000
3	7.50	-791	0	50	-0.11	-0.03	90.0	-7.0	0.000	0.000
3	6.00	-804	0	51	-0.11	-0.03	90.0	-7.0	0.000	0.000
3	4.50	-818	0	52	-0.11	-0.03	90.0	-7.0	0.000	0.000
3	3.00	-831	0	54	-0.11	-0.03	90.0	-7.0	0.000	0.000
3	1.50	-844	0	56	-0.12	-0.03	90.0	-7.0	0.000	0.000
3	0.00	-858	0	57	-0.12	-0.03	90.0	-7.0	0.000	0.000

Foundation loads (2nd order theory)

EQU	Limit state of the safety against displacement	BS-P	Permanent situation
STR	Ultimate limit state for the structural member design	BS-A	Accidental situation
GEO-2	Limit state in the subsoil with characteristic CoA (γ = 1.0 and $\psi_{0,i} = \psi_{0,i\ STR}$)	BS-E	Earthquake situation
CHAR	characteristic loads (γ = 1.0 and ψ_i = 1.0)		

LCC	Type	Situation	P_z [kN]	M_x^I [kNm]	M_y^I [kNm]	H_x^I [kN]	H_y^I [kN]	ΔM_x^{II} [kNm]	ΔM_y^{II} [kNm]	ΔH_x^{II} [kN]	ΔH_y^{II} [kN]
1	GEO-2	BS-P	833.0	0.0	-43.5	0.0	0.0	0.0	-42.3	0.0	0.0
1	STR	BS-P	1124.6	0.0	-58.7	0.0	0.0	0.0	-63.4	0.0	0.0
2	GEO-2	BS-P	958.0	0.0	-111.0	5.0	0.0	0.0	-68.4	0.0	0.0
2	STR	BS-P	1312.1	0.0	-160.0	7.5	0.0	0.0	-122.5	0.0	0.0
3	GEO-2	BS-A	958.0	0.0	-111.0	5.0	0.0	0.0	-37.5	-4.0	0.0
3	STR	BS-A	858.0	0.0	-57.0	1.0	0.0	0.0	-91.6	0.0	0.0

Shear force bearing capacity

Minimum shear force reinforcement is not considered.

Height [m]	LCC	b_w [cm]	V_{Ed} [kN]	V_{Rdc} [kN]	V_{Rdmax} [kN]	Theta [°]	z_i [cm]	$A_{s,w}$ [cm²/m]	Direction
12.00	2	60.0	7.5	288.1	1862.4	45	48.7	0.00	x
10.50	2	60.0	7.5	290.1	1862.4	45	48.7	0.00	x
9.00	2	60.0	7.5	292.1	1862.4	45	48.7	0.00	x
7.50	2	60.0	7.5	294.0	1862.4	45	48.7	0.00	x
6.00	2	60.0	7.5	296.0	1862.4	45	48.7	0.00	x
4.50	2	60.0	7.5	298.0	1862.4	45	48.7	0.00	x
3.00	2	60.0	7.5	299.9	1862.4	45	48.7	0.00	x
1.50	2	60.0	7.5	301.9	1862.4	45	48.7	0.00	x
0.00	2	60.0	7.5	303.9	1862.4	45	48.7	0.00	x
12.00	0	60.0	0.0	0.0	0.0	0	0.0	0.00	y
10.50	0	60.0	0.0	0.0	0.0	0	0.0	0.00	y
9.00	0	60.0	0.0	0.0	0.0	0	0.0	0.00	y
7.50	0	60.0	0.0	0.0	0.0	0	0.0	0.00	y
6.00	0	60.0	0.0	0.0	0.0	0	0.0	0.00	y
4.50	0	60.0	0.0	0.0	0.0	0	0.0	0.00	y
3.00	0	60.0	0.0	0.0	0.0	0	0.0	0.00	y
1.50	0	60.0	0.0	0.0	0.0	0	0.0	0.00	y
0.00	0	60.0	0.0	0.0	0.0	0	0.0	0.00	y

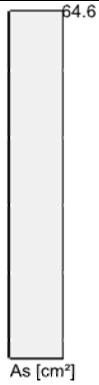
Analysis summary

Imperfection	is being considered
Load bearing capacity (geometrical+physical non-linear)	was carried out
Shear force bearing capacity	was carried out
Structural fire protection	R90 fulfilled acc. to the extended zone method
Load transfer to FUNDA (bif file)	yes
total longitudinal reinforcement (without bond lengths etc.)	608.0 kg

Summary of the required reinforcement

No smaller reinforcement than applied for the calculation of the section displacements may be laid out. The reinforcement is to be laid out symmetrically in the cross-section.
Th. = 1 Minimum reinforcement acc. to 1st order theory; Th. = 2 design acc. to 2nd order theory decisive

Height [m]							required reinforcement					
from	to	Type	Shape	relev. LCC	Th.	d_1 [cm]	A_s/A_c [%]	$A_{s,L}$ [cm²]	$A_{s,w}$ [cm²/m]	n_{req}	exis∅$_{s,L}$ [mm]	selected
12.00	0.00	R	4Edges	3	2	5.9	1.79	64.6	0.00	-	-	


64.6
As [cm²]