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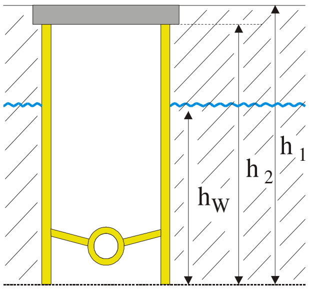
Structural calculation of shaft constructions according to ATV A 127

Project:	Manhole ID 1000
Date:	22.09.16

Input values:

Installation



(basic sketch)

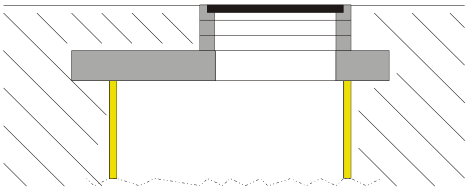
Installation depth (h1):	h_1	6.300	mm
Length of shaft pipe (h2):	h_2	6.000	mm
Height groundwater (hw):	h_w	3.000	mm
Density of soil:	γ_s	20,0	kN/m³
Slope angle Beta:	β	0,0	°
Bedding			
Soil group:	G1		
Proctor density:	$D_{PR,2}$	98,0	%
Existing soil			
Soil group:	G1		
Proctor density:	$D_{PR,2}$	95,0	%
Traffic load adjacent to shaft lid	HLC 60		

Assumptions

Safety class:	A (normal case)		
Pre-deformation due to structural imperfection:	$\delta_{V,\,l,s}$	0,50	%
Pre-deformation due to geometric imperfection:	$\delta_{V,\,l,g}$	0,50	%
Working area:	b	1.500	mm
Factor of inequality (usually 0.6-0.7):	Ω	0,8	[1]
Support factor Beta for ax. buckl. proof:	β	2,50	[1]
Horizontal soil pressure	Plane active approach		
Casing friction angle	1/3 soil friction angle (standard case)		

Lid construction type

Simple, supported reinforced concrete lid

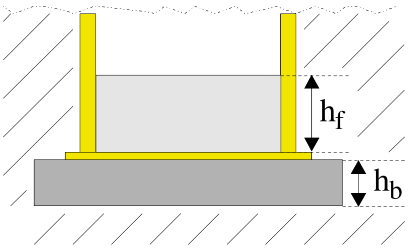


(basic sketch)

Inside diameter entrance:	$D_{i,E}$	600	mm
Thickness of plate:	s_L	300	mm
Diameter of concrete plate:	D_L	2.200	mm
Traffic load on the whole shaft lid:	HLC 60		

Bottom construction type

Based on foundation plate



(basic sketch)

Concrete filling (hf):	h_f	0	mm
Thickness of bottom plate:	s_B	30	mm
Type of welding seam:	no seam/dimensioning		
Concrete quality of foundation plate:	B15		
Concrete steel:	BSt 500 S/M		
Thickness of foundation plate (hb):	h_b	150	mm
Diameter of foundation plate:	D_b	1.400	mm

Connection pieces/openings

No connection pieces or gaps.

Things built in

Weight of things built in at the shaft casing:	G_{M+}	0,00	kN
Weight of things built in on shaft bottom:	G_{B+}	0,00	kN

Pipe

Description:	Vollwand		
Inside diameter:	d_i	1.000,0	mm
Wall thickness:	s	25,00	mm

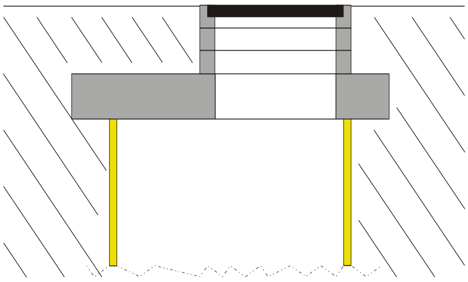
Pipe material

Material class:	Thermoplastic
Description:	Borealis PE100 HE3490-LS (Borstar HE3490-LS)

Density of pipe material	γ_P	9,40	kN/m³
Transv. contr. coeff.	ν	0,38	[1]
E-Modulus, short	E_{st}	1.203,00	N/mm²
E-Modulus, long	E_{lt0}	292,00	N/mm²
Ultimate flexural tensile stress, short-term	$\sigma_{BT,st}$	29,90	N/mm²
Ultimate flexural compressive stress, short-term	$\sigma_{BC,st}$	49,90	N/mm²
Ultimate flexural tensile stress, long-term	$\sigma_{BT,lt}$	20,90	N/mm²
Ultimate flexural compressive stress, long-term	$\sigma_{BC,lt}$	34,90	N/mm²

Results for lid

Calculation of lid weight



(basic sketch)

Assumptions

Soil density:	$\gamma_{concrete}$	25,0	kN/m³
Weight of passavant (d 80cm):	$G_{passavant,80}$	1,00	kN
Thickness of compensation ring:	$S_{compens.}$	100	mm
Height of compensation ring:	$h_{compens.}$	100	mm

Intermediate results:

Height of lid:	h_{lid}	300	mm
Influence diameter:	$D_{influence}$	2.200	mm
Number of compensation rings:	$n_{compens.}$	0	[1]
Total weight of compensation rings:	$G_{compens.}$	0,00	kN
Weight of plate:	G_{plate}	26,39	kN
Weight of soil above plate:	$G_{soil, plate}$	0,00	kN
Weight of passavant:	$G_{passavant}$	0,56	kN
Number of wheels on lid construction:	n_{wheels}	2	[1]
Weight of wheels:	G_{wheels}	100,00	kN
Impact coefficient of wheels:	f_{wheels}	1,2	[1]

Results:

Dead weight of lid (max.) (incl. earth load):	$G_{lid, max}$	26,95	kN
Dead weight of lid (min.) (incl. earth load):	$G_{lid, min}$	26,39	kN
Traffic load on lid:	P_{lid}	240,00	kN

Soil stress adjacent to lid:

Height of lid:	h_{lid}	300	mm
Soil density	ω_{soil}	20,0	kN/m³
Vertical soil stress at shaft upper edge due to earth load:	$q_{00,E,v}$	6,0	kN/m²

Summary:

Dead weight of lid (max.) (incl. earth load):	$G_{lid, max}$	26,95	kN
Dead weight of lid (min.) (incl. earth load):	$G_{lid, min}$	26,39	kN
Traffic load on lid	$G_{t, lid}$	240,0	kN
Induced axially into the shaft casing (max.):	$G_{00, max}$	26,95	kN
Induced axially into the shaft casing (min.):	$G_{00, min}$	26,39	kN
Axially induced traffic load:	P_{00}	240,00	kN
Vert. soil stress at u. edge of shaft due to earth load:	q_{00}	6,0	kN/m²

Proofs for shaft casing (500 mm below the upper edge of the site)

Soil:

Transversal contraction coefficient of soil:	ν	0,20	[1]
Modulus of deformation of existing soil:	E_3	15,640	N/mm²
Modulus of deformation bedding:	E_2	27,491	N/mm²
Resulting modulus of stiffness:	$E_{S,m}$	28,303	N/mm²

The resulting modulus of stiffness is determined from:
$E_{S,m} = (1-\nu^2)\,(1-\nu)/(1-\nu-2\nu^2) \cdot 1{,}5\ D_a\ /\ [b/E_2 + (1{,}5\ D_a - b)/E_3]$

Interior friction angle	φ	35,00	°
Wall friction angle	δ	-11,67	°
Correction value for the horizontal bedding stiffness:	ξ	0,969	[1]
Horizontal bedding stiffness:	S_B	15.976,6	kN/m²

Depths down to dimensioning level:

Distance from level of dimensioning to shaft foot:	h'	5.800	mm
Cover above level of dimensioning:	h_1'	500	mm
Shaft pipe length above level of dimensioning:	h_2'	200	mm
Height of concr. ring against lift. force above dim. level:	h_a'	0	mm
Ground water level above level of dimensioning:	h_W'	0	mm
Dry earth load between lid and level of dimensioning:	$h_{E,tr}$	200	mm
Earth load under water between lid and level of dim.:	$h_{E,W}$	0	mm

Coefficient for the horizontal earth pressure:

Ground pressure coefficient (plane, active approach):	K_{ah}	0,246	[1]

$$k_{ah} = \frac{\cos^2 \rho}{\left[1 + \sqrt{\frac{\sin(\varphi' - \delta_a) \cdot \sin(\varphi' - \beta)}{\cos\delta \cdot \cos\beta}}\right]^2}$$

Effects of connection pieces:

Axially operating shaft casing surface:	A_{gross}	80.503	mm²
Area attenuated by connection pieces:	$A_{ax,net}$	80.503	mm²
Reduction factor for ring stiffness:	κ_R	1,00	[1]
Reduction factor surface and section modulus:	κ_W	1,00	[1]

Loads and stresses operating in radial direction across the soil onto the shaft

Vert. soil stress at upper edge of shaft (earth load): (Preliminary results from observing the lid)	$q_{00,E,v}$	6,0	kN/m²
Add. earth load (up. edge of shaft up to level of dim.):	$q_{zus,E,v}$	4,0	kN/m²
Tot. vert. soil stress due to earth and surface load:	$q_{E,v}$	10,0	kN/m²
Vertical soil stress due to traffic load:	$q_{V,}$v	88,1	kN/m²

The traffic load adjacent to the shaft is determined according to ATV-DVWK A 127.

Assumed minimum distance:	l_{min}	500	mm

Note: This horizontal minimum distance of traffic adjacent to the shaft is to be observed or the calculation will lose its validity.

Background: This minimum distance results from the restriction that equations for stress due to traffic load are only valid from a certain minimum height of cover, and equal to a horizontal minimum distance if the load distribution is assumed to be 1:1.

Horizontal stresses, radially effective on the shaft through the soil:

Horiz. soil stress due to earth and surface load: $q_{E,h} = (q_{00} + q_{zus}) \cdot K_{ah}$	$q_{E,h}$	2,5	kN/m²
Horizontal soil stress due to traffic load: $q_{V,h} = q_{V,v} \cdot K_{ah}$	$q_{V,h}$	21,6	kN/m²
Stress due to groundwater:	$q_{W,h}$	0,0	kN/m²

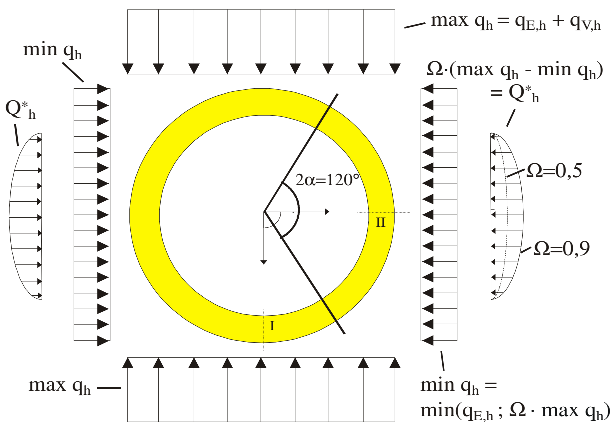
(Radial loading-dependent) material characteristic values of the shaft pipe and resulting values:

For materials with loading period-dependent material characteristic values (especially plastics) weighted from the long-term and short-term values in the ratio of the lasting and short-term loads. As the ratio of these loads differs in radial and axial direction different calculated values will be used.
$E_{rad} = (E_K \cdot q_{hV} + E_L \cdot q_{hE}) / (q_{hV} + q_{hE})$

		short term	long term	weighted	
E-Modulus:	E	1.203,0	292,0	1.110,1	N/mm²
Ultimate flexural tensile stress:	σ_{BZ}	29,9	20,9	29,0	N/mm²
Ultimate flexural compressive stress:	σ_{BD}	29,9	20,9	29,0	N/mm²

Ring stiffness of shaft pipe (without connection piece):	S_{R0}	10,7	kN/m²
Ring stiffness of shaft pipe (with connection piece):	S_R	10,7	kN/m²
System stiffness:	V_{RB}	0,0007	[1]
Coefficient for the bedding reaction pressure:	K*	1,2532	[1]

Horizontal earth pressure distribution



Irregularity factor:	Ω	0,80	[1]
Maximum horizontal soil stress (section I):	max q_h	24,1	kN/m²

Max q_h results from total of horizontal stresses from earth load, surface and traffic load: max $q_h = q_{E,h} + q_{V,h}$

Minimum horizontal soil stress (section II):	min q_h	2,5	kN/m²

Min q_h is determined like max q_h, but without traffic load: it is limited to a maximum value, in order to take the unsymmetric character of the installation into account: min $q_h = q_{e,h}$ and maximum $\Omega \cdot$ max q_h

Bedding reaction pressure:	q_h*	21,7	kN/m²

q_h* results as $\Omega \cdot$ (max q_h - min q_h) $\cdot$ K* ; Ω takes into consideration unsymmetries due to installation condition and quality of installation

Section forces in radial direction

		Section I	Section II	
Moment according to max q_h:	$M_{max\ qh}$	1,58	-1,58	kNm/m
Axial force according to max q_h:	$N_{max\ qh}$	0,000	-12,347	kN/m
Moment according to q_h:	$M_{min\ qh}$	-0,16	0,16	kNm/m
Axial force according to min q_h:	$N_{min\ qh}$	-1,259	0,000	kN/m
Moment according to bedding reaction	M_{qh*}	-1,03	1,19	kNm/m
Axial force according to bedding reaction:	N_{qh*}	-6,414	0,000	kN/m

Moment according to groundwater:	M_{pw}	0,00	0,00	kNm/m
Axial force according to groundwater:	N_pw	0,000	0,000	kN/m
Total bending moments:	ΣM	0,39	-0,24	kNm/m
Total axial forces:	ΣN	-7,673	-12,347	kN/m

Loads and stresses operating in axial direction in the shaft casing

Preliminary results from oberving the lid:

Axially induced into the shaft casing (max.):	$G_{00,\,max}$	26,95	kN
Axially induced traffic load:	P_{00}	240,00	kN

Additional loads:

Dead weight of shaft pipe:	G_g	0,16	kN

The dead weight will be calculated without considering possible connection pieces/openings.

Casing friction:	T_M	0,42	kN

$T_M = 1/2 \cdot \tan(\delta) \cdot q_{e,h} \cdot \pi \cdot d_a \cdot (h_1' - h_a')$

The complete shaft casing incl. constructions on the lid above the dimensioning level and above a possibly existing concrete ring against lifting force without reduction of possible connection pieces/openings is assumed as rubbing casing area. As a simplification the constructions on the lid are assumed to have the same external diameter as the shaft.

Stresses:

Reference area	A_{netto}	80.503	mm²
Axial stress due to dead weight + things built in:	$\sigma_{G,ax}$	0,002	N/mm²
Axial stress due to casing friction:	$\sigma_{M,ax}$	0,005	N/mm²
Axial stress due to traffic on the lid:	$\sigma_{P,ax}$	2,981	N/mm²
Axial stress due to lid load:	$\sigma_{Q00,ax}$	0,335	N/mm²
Total axial stress at shaft foot:	$\Sigma\sigma_{ax}$	3,323	N/mm²

(Axial loading-dependent) material characteristic values of shaft pipe:

For materials with loading period-dependent material characteristic values (especially plastics) the material properties' calculated values are weighted from the long-term and short-term values in the ratio of the long-term and short-term loads. As the ratio of these loads differs in radial and axial direction different calculated values will be used.

$E_{ax} = (E_{ax,K} \cdot \sigma_{ax,V} + E_{ax,L} \cdot (\Sigma\sigma_{ax} - \sigma_{ax,V}) / \Sigma\sigma_{ax}$

		short term	long term	weighted	
E-Modulus:	E	1.203,0	292,0	1.109,3	N/mm²
Ultimate flexural tensile stress:	σ_{BZ}	29,9	20,9	29,0	N/mm²
Ultimate flexural compressive stress:	σ_{BD}	29,9	20,9	29,0	N/mm²

Deformation proof in radial direction

Change of diameter due to earth pressure:	δ_V	3,86	%

$\delta_V = |c_{v,qv} \cdot \max q_h + c_{v,qh} \cdot \min q_h + c_{v,qh^*} \cdot q_h^*| / S_R \cdot 100\%$

$\delta_V = |-0.0833 \cdot \max q_h + 0.0833 \cdot \min q_h + 0.064 \cdot q_h^*| / S_R \cdot 100\%$

Pre-deformtation due to structural imperfection:	$\delta_{V,\,I,s}$	0,50	%
Pre-deformation due to geometric imperfection:	$\delta_{V,\,I,g}$	0,50	%
Total deformation:	$\Sigma\delta_V$	4,86	%
Admissible total deformation:	$\delta_{V,zul}$	6,00	%

The total deformation is in the admissible range.

Stress proof in radial direction

Ultimate flexural tensile stress:	σ_{bZ}	28,98	N/mm²
Ultimate flexural compressive stress:	σ_{bD}	48,37	N/mm²

Internal		Section 1	Section 2	
Stress internal:	σ_i	3,493	-2,793	N/mm²
Safety flexural tension:	$\gamma_{\varepsilon i,\,BT}$	8,30	---	[1]
Safety flexural compression:	$\gamma_{\varepsilon i,\,BC}$	---	17,32	[1]

External		Section 1	Section 2	
Stress external:	σ_e	-3,985	1,732	N/mm²
Safety flexural tension:	$\gamma_{\varepsilon e, BT}$	---	16,73	[1]
Safety flexural compression:	$\gamma_{\varepsilon e, BC}$	12,14	---	[1]

Minimum flexural compression safety:	$\gamma_{\sigma BC,min}$	1,50	[1]
Minimum flexural tension safety:	$\gamma_{\sigma BT,min}$	2,50	[1]

The existing safeties are sufficient.

<u>Stress proof in axial direction</u>

Ultimate flexural compressive stress in axial direction:	$\sigma_{bD,ax}$	48,36	N/mm²
Stresses from axial forces at dimensioning level:	$\Sigma\sigma_{ax}$	3,32	N/mm²

		internal	external	
Axial stress resulting at dimensioning level:	σ_{ax}	-3,32	-3,32	N/mm²
Existing safety:	γ_{ax}	14,55	14,55	N/mm²
Required safety:	erf γ_{ax}	1,50	[1]	

The axial stress safety is sufficient.

<u>Stability proof in radial direction</u>

Buckling proof against water pressure:

External water pressure:	p_a	0,000	N/mm²
Periodicity of buckling proof according to Sonntag:	$m_{Sonntag,pa}$	5,90	[1]
Calculated with weighted long-term E-modulus:	E_L	292,000	N/mm²
Critical buckling pressure (water pressure):	$p_{Ki,pa}$	0,122	N/mm²

Buckling proof against earth pressure:

Radial pressure due to earth and traffic loads:	$q_{E,h}$	0,024	N/mm²
Periodic number of the buckl. proof acc. to Sonntag:	$m_{Sonntag,qE,h}$	4,70	N/mm²
Calculated with weighted E-modulus:	E	1.110,107	N/mm²
Critical buckling pressure (earth pressure):	$p_{Ki,qE,h}$	0,304	N/mm²
Minimum safety stability:	$\gamma_{Stab, min}$	2,00	[1]
Existing radial safety against buckling:	$\gamma_{Stab, rad}$	12,63	[1]

$\gamma_{Stab, rad} = 1 / [(q_{E,h} / p_{Ki,qE,h}) + (p_a / p_{Ki,pa})]$

The radial safety against buckling is sufficient!

<u>Stability proof in axial direction</u>

Factor Alpha:	α	0,474	[1]

$\alpha = 0{,}52 / [1 + r_m/(100 \cdot A_{ax})]^{1/2}$

Support factor Beta due to bedding:	β	2,500	[1]
Minimum safety stability:	$\gamma_{Stab, min}$	2,00	[1]
Ideal buckling stress:	σ_{Ki}	33,774	N/mm²

$\sigma_{Ki} = E / (3 \cdot (1-\nu^2))^{1/2} \cdot$ profile height/r_m

Critical buckling stress:	krit σ_{Ki}	39,998	N/mm²

krit $\sigma_{Ki} = \alpha \cdot \beta \cdot \sigma_{Ki}$

Existing axial stress:	σ_{ax}	3,323	N/mm²
Existing axial safety against buckling:	$\gamma_{Stab, ax}$	12,04	[1]

The axial safety against buckling is sufficient.

<u>Interaction proof for radial and axial buckling</u>

Existing axial safety against buckling:	$\gamma_{Stab, ax, L}$	12,04	[1]
Existing radial safety against buckling:	$\gamma_{Stab, rad}$	12,63	[1]
Interaction value:		0,21	[1]

The interaction value results as $(\gamma_{Stab, rad, L} / \gamma_{Stab, min})^{1,25} + (\gamma_{Stab, ax, L} / \gamma_{Stab, min})^{1,25}$

The interaction value is below the admissible maximum value of 1.0.

Proofs for bottom plate and welding

Preliminary results and assumptions

Length of shaft pipe:	h_2	6.000	mm
Height of groundwater:	h_w	3.000	mm
Height of concrete filling:	h_f	0	mm
Thickness of bottom plate:	s_B	30,0	mm
Relaxation factor:	f_R	1,4	[1]

In the case of thermoplastics (esp. PE-HD) the bending moments of the bottom plate can bereduced due to relaxation.

Horizontal stress at shaft foot:

Horiz. soil stress due to traffic load:	$q_{V,h}$	1,8	kN/m²
Horiz. soil stress due to earth and surface load:	$q_{E,h}$	24,3	kN/m²
Water pressure:	$q_{W,h}$	30,0	kN/m²

Cutting forces from the theory of thin shells without considering the torsion (δ-method):

The axial forces from the theory of thin shells are calculated with weighted material characteristic values. $q_{V,h}$ short-term effective, $q_{E,h}$ and $q_{W,h}$ long-term effective.

		short term	long term	weighted	
E-Modulus:	E	1.203,0	292,0	321,3	N/mm²
Ultimate flexural tensile stress:	σ_{BZ}	29,9	20,9	21,2	N/mm²
Ultimate flexural compressive stress:	σ_{BD}	29,9	20,9	21,2	N/mm²

Elastic fixing of bottom plate has been assumed.

Bending moment bottom plate/casing (edge disturb.):	M_E	-0,04	kNm/m
Transverse force bottom plate/casing (edge disturb.):	Q_E	2,788	kN/m

For comparison: bending moment analogous to containers with compulsory mark of conformity:

Assumed as wall thickness:	s_e	25,0	mm
Bending moment bottom plate/casing:	$M_{Z,E}$	0,55	kNm/m

Formula: $0,1 \cdot \Sigma_{QH} \cdot 2 \cdot r_m \cdot s_e \cdot 1/f_R$

Bending moment midspan:

In the field core calculations are carried out with long-term material characteristic values, ground water and concrete filling being long-term givings, while the soil compression (including traffic load shares) is insignificant for materials with loading period-dependent material characteristic values.

Assumed bedding:	bedded freely rotatable		
Factor m acc. to Petersen/steel engineering:	m	4,73	[1]
Factor 1/m:	1/m	0,21	[1]
Water pressure, affecting bottom plate from below:	p_W	30,0	kN/m²
Counterpressure from dead weight of concrete filling:	p_{BF}	0,0	kN/m²
Resulting pressure on bottom plate:	$p_{W,res}$	30,0	kN/m²
Flow factor:	f_f	1,4	[1]
Bending moment midspan:	$M_{Z,M}$	1,19	kNm/m

Formula: $1/m \cdot r_m\ 2 \cdot p_{W,res} \cdot 1/f_F$

Stress proof edge

(carried out with weighted material characteristic values, see above!)

		top	bottom	
Stress bottom plate/casing:	$\sigma_{B,E}$	-0,334	0,148	N/mm²
Existing flexural tension safety:	$\gamma_{\sigma B,E,\ BT}$	---	143,18	[1]
Existing flexural compression safety:	$\gamma_{\sigma B,E,\ BC}$	105,98	---	[1]

Formula: $\pm\ \sigma_{B,E} = M_E \cdot 6/s_B^2 - Q_E/s_B$

Allowed flexural tensile stress:	$\sigma_{BT,L}$	21,19	N/mm²
Allowed flexural compressive stress:	$\sigma_{BC,L}$	35,38	N/mm²
Minimum flexural tension safety:	$\gamma_{\sigma BT,min}$	2,50	[1]
Minimum flexural compression safety:	$\gamma_{\sigma BC,min}$	1,50	[1]

The existing safety is sufficient.

<u>Stress proof midspan</u>

(carried out with long-term material characteristic values, see above!)

		top	bottom	
Stress midspan:	$\sigma_{B,M}$	7,834	-8,020	N/mm²
Formula: $\sigma_{B,M} = \pm M_{Z,M} \cdot 6/s_B^2 - Q_E/s_B$				
Existing flexural tension safety:	$\gamma_{\sigma B,M,\ BT}$	2,67	---	[1]
Existing flexural compression safety:	$\gamma_{\sigma B,M,\ BC}$	---	4,35	[1]

Allowed flexural tensile stress:	$\sigma_{BT,L}$	21,19	N/mm²
Allowed flexural compressive stress:	$\sigma_{BC,L}$	35,38	N/mm²
Minimum flexural tension safety:	$\gamma_{\sigma BT,min}$	2,50	[1]
Minimum flexural compression safety:	$\gamma_{\sigma BC,min}$	1,50	[1]

The existing safety is sufficient.

Lifting force proof

Assumptions and preliminary results

Lid weight on shaft casing (min.):	$G_{00, min}$	26,39	kN
Dead weight of the shaft casing	G	4,65	kN
Dead weight of bottom plate:	G_B	0,00	kN

Intermediate results

Weights

Lid weight on shaft casing (min.):	$G_{00, min}$	26,39	kN
Dead weight of the shaft casing	G	4,65	kN
Dead weight of bottom plate:	G_B	0,00	kN
Weight of concrete filling:	G_f	0,00	kN
Sum of weights:	ΣG	31,04	kN

Displaced volumes

Volume of the shaft piece under water:	V_{shaft}	2,60	m³
Sum of displaced volumes:	ΣV	2,60	m³

Result

Sum of weights:	ΣG	31,04	kN
Weight of displaced water volume:	G_V	25,98	kN
Minimum safety lifting force:	$\gamma_{A, min}$	1,10	[1]
Existing safety against lifting force:	γ_A	1,19	[1]

Lifting force safety is sufficient.

Reinforcement dimensioning of foundation plate

Effective total weight (maximum)

Ax. soil stresses at upper shaft edge (earth load):	q_{00}	6,0	kN/m²
Ax. soil str. (traffic) at up. edge ring against lift. force:	$q_{traffic,ha}$	7,3	kN/m²
Projection area of bottom construction:	A_{ring}	673.479	mm²
Total load of lid (incl. traffic):	$t_{lid,\ max}$	266,95	kN
Weight soil ring (ground level - top shaft)	$G_{00,\ ring}$	4,04	kN

To be on the safe side it is assumed that q_{00} operates on the whole projection surface of the concrete plate.

Dead weight of shaft casing:	G	4,65	kN
Casing friction:	T_M	52,18	kN
Weight soil ring top of shaft - top of foundation	G_{ring}	80,82	kN

To be on the safe side the density of the soil in the case of ground water is not reduced.

Traffic load in foundation ring:	$G_{traffic,Ring}$	4,95	kN
Dead weight of bottom plate:	G_B	0,24	kN
Force resulting from water pressure:	F_{GW}	24,98	kN

Formula: $F_{GW} = (s_B + h_w) \cdot \gamma_W \cdot \pi/4 \cdot d_i^2$
To be on the safe side the concrete filling and water pressure will not be added to each other.

Weight of reinforced concrete foundation plate:	G_{StbF}	5,77	kN
Total load:	G_{total}	444,58	kN
Effective diameter:	$D_{effective}$	1.400	mm
Soil compression:	q_B	288,81	kN/m²

Dimensioning

Structural height:	h	105	mm
Shear force in foundation plate:	q	0,289	kN/m
Maximum bending moment in foundation plate:	m_S	14,23	kNm/m

Formula: $M_S = 1/(5{,}33) \cdot q \cdot r_m^2$

Shear force in foundation plate:	zug q	0,074	kN

Formula: zug $q = 1/(2{,}0) \cdot q \cdot r_m^2$

Dimensioning coefficient:	k_h	2,783	[1]
Dimensioning coefficient:	k_s	4,100	[1]
Required reinforcement (top and bottom):	req $A_{S,rad}$	5,56	cm²/m

This required cross-section applies for radial reinforcement, for usage of rectangular mats applies:

Required reinforcement, rectangular mats:	req A_S	7,86	cm²/m

Dimensioning of thrust reinforcement

Shearing strain:	τ_0	0,83	MN/m²
Upper limit of shearing strain fundamental values:	τ_{02}	1,20	MN/m²
Lower limit of shearing strain fundamental values:	τ_{011}	0,25	MN/m²
Assumed concrete height:	h	150	mm
Reduction coefficient for τ_{011}:	k_1	1,00	[1]
Required thrust reinforcement:	erf $A_{S\tau}$	0,20	cm²/m