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Calculations to ATV-DVWK-A 127, third edition, August 2000

Project:	ID1200 PANCEVO
Client:	PIPELIFE Srbia
Statics No.:	16/163
Date:	22.09.16
Contact:	Denisa Djordjevic
E-mail:	denisa.djordjevic@pipelife.com

Input:

Safety factors

Safety class:	A (normal case)		
Allowable deflection:	6% (normal case)		
A type predeformation:	$\delta_{v,TypeA}$	1,00	%
Local predeformation:	$\delta_{v,local}$	0,00	%

Pipe

Manufacturer:	Krah d.o.o		
Profil-Reihe:	Profilrohr		
Description:	PR-75-014.61		
Inside diameter:	d_i	1.200,0	mm
Profile width:	b	140,00	mm
Profile height:	h	85,00	mm
Profile surface:	A_{rad}	17,10	mm²/mm
Axially effective profile surface:	A_{ax}	13,00	mm²/mm
Moment of inertia:	J	14.612,00	mm⁴/mm
Distance of inertia:	e	28,81	mm
Equivalent wall strength:	s_e	56,00	mm
Moment of resistance (internal):	W_i	507,20	mm³/mm
Moment of resistance (external):	W_e	260,00	mm³/mm
Surface ratio Kappa Q:	κ_Q	1,20	[1]
Ringstiffness EN - ISO 9969	SN	8,00	kN/m²

Pipe material

Material class:	Thermoplastic		
Description:	Borealis PE-100 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

Soil

E1: Backfilling:	Soil group: G1		
Proctor density:	D_{PR1}	95,0	%
E20: Pipe zone:	Soil group: G1		
Proctor density:	D_{PR2}	95,0	%
E3: Native soil:	Soil group: G2		
Proctor density:	D_{PR3}	92,0	%
E4: Below trench:	Soil group G2		
Proctor density:	D_{PR4}	92,0	%

Installation

Trench width:	b	2.200	mm
Slope angle:	β	90,00	°
Cover condition:	A1		
Bedding condition:	B1		
Type of bedding:	loose		
Relative projection:	a	1,00	[1]
Bedding angle:	120°		

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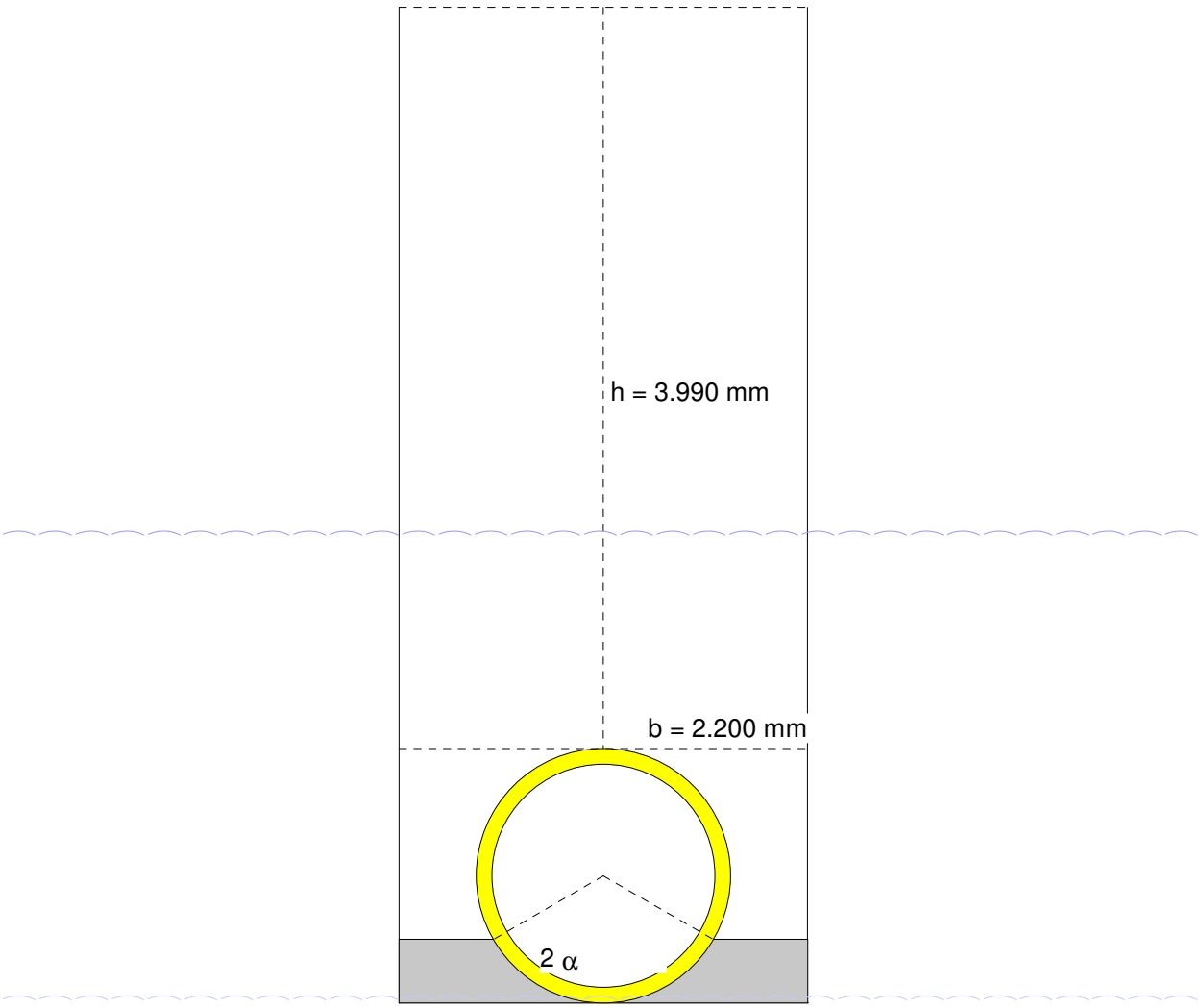
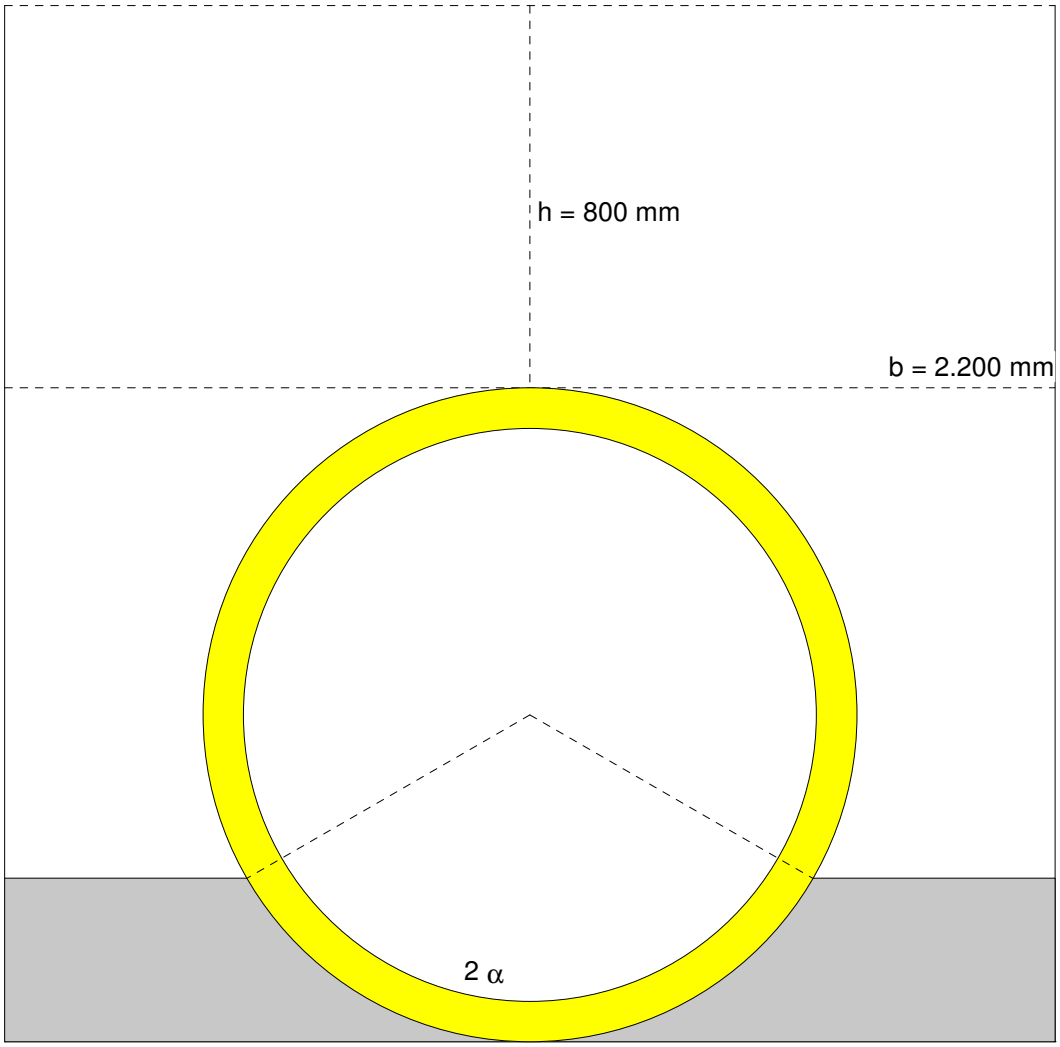
Load case combination 1

Description:	Area with maximum cover		
Cover depth:	h	3.990	mm
Soil density:	γ	20,00	kN/m³
Additional surface load:	P_0	0,00	N/mm²
Maximum groundwater level above pipe bed:	$h_{W,max}$	2.500	mm
Minimum groundwater level above pipe bed:	$h_{W,min}$	0	mm
Internal pressure:	P_I	0,00	bar
Water fill (e.g. damming channel)	Yes		
Density of medium:	γ_F	10,00	kN/m³
Traffic load:	HLC 60 (road)		



Load case combination 2

Description:		Area with minimum cover	
Cover depth:	h	800	mm
Soil density:	γ	20,00	kN/m³
Additional surface load:	P_0	0,00	N/mm²
Maximum groundwater level above pipe bed:	$h_{W,max}$	0	mm
Minimum groundwater level above pipe bed:	$h_{W,min}$	0	mm
Internal pressure:	P_I	0,00	bar
Water fill (e.g. damming channel)		Yes	
Density of medium:	γ_F	10,00	kN/m³
Traffic load:		HLC 60 (road)	



Proof for load case combination 1, Short term

Stress proof (with minimum groundwater):

Calculated ultimate flexural tensile stress, soil/traffic load:	$\sigma_{,calc,BZ}$	29,9	N/mm²
Calculated ultimate flexural compr. stress, soil/traffic load:	$\sigma_{,calc,BD}$	49,9	N/mm²
Ultimate flexural tensile stress due to other loads:	$\sigma_{all,BZ}$	29,9	N/mm²
Ultimate flexural compressive stress due to other loads:	$\sigma_{all,BD}$	49,9	N/mm²

Internal:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,i}$	0,878	-5,805	1,727	N/mm²
Stress due to other loads:	$\sigma_{other,i}$	0,368	-0,339	0,915	N/mm²
Safety:	γ_{BTi}	24,01	---	11,32	[1]
Safety:	γ_{BCi}	---	8,12	---	[1]

External:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,a}$	-8,46	1,12	-10,48	N/mm²
Stress due to other loads:	$\sigma_{other,a}$	-0,53	0,72	-1,03	N/mm²
Safety:	γ_{BTe}	---	16,25	---	[1]
Safety:	γ_{BCe}	5,55	---	4,34	[1]

Required flexural tensile safety:	req γ_{BT}	2,50	[1]
Required flexural compressive safety:	req γ_{BC}	2,50	[1]

The stress safety factors determined are greater than the required factors.

Stress proof (with maximum groundwater):

Calculated ultimate flexural tensile stress, soil/traffic load:	$\sigma_{,calc,BZ}$	29,9	N/mm²
Calculated ultimate flexural compr. stress, soil/traffic load:	$\sigma_{,calc,BD}$	49,9	N/mm²
Ultimate flexural tensile stress due to other loads:	$\sigma_{all,BZ}$	29,9	N/mm²
Ultimate flexural compressive stress due to other loads:	$\sigma_{all,BD}$	49,9	N/mm²

Internal:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,i}$	0,976	-5,275	1,733	N/mm²
Stress due to other loads:	$\sigma_{other,i}$	-0,665	-1,372	-0,117	N/mm²
Safety:	γ_{BTi}	51,70	---	17,98	[1]
Safety:	γ_{BCi}	---	7,51	---	[1]

External:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,a}$	-7,78	1,18	-9,57	N/mm²
Stress due to other loads:	$\sigma_{other,a}$	-1,48	-0,23	-1,98	N/mm²
Safety:	γ_{BTe}	---	28,69	---	[1]
Safety:	γ_{BCe}	5,39	---	4,32	[1]

Required flexural tensile safety:	req γ_{BT}	2,50	[1]
Required flexural compressive safety:	req γ_{BC}	2,50	[1]

The stress safety factors determined are greater than the required factors.

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Deflection proof (with minimum groundwater):

Calculation method:		linear		
Ratio:		$I/(A_{rad} \cdot r_m^2)$	0,00216	[1]
Ratio:		$I/(A_{rad} \cdot r_m^2) \cdot \kappa_q$	0,00259	[1]

		q_v	q_h	q_h^*	
Deflection coefficient for bending moments:	c_v	-0,0893	0,0833	0,0640	[1]
Deflection coefficient for axial forces:	cN_v	-0,683	-0,681	-0,247	[1]
Deflection coefficient for lateral forces:	cQ_v	-0,359	0,335	0,243	[1]
Resultant deflection coefficient:	c'_v	-0,0933	0,0842	0,0652	[1]

Vertical diameter change:	Δd_v	29,4	mm
Horizontal diameter change:	Δd_h	20,1	mm
Relative vertical deformation:	δ_v	2,34	%
Allowable deflection:	all d_v	6,00	%

The deflection determined is less than the allowable deflection.

Deflection proof (with maximum groundwater):

Calculation method:		linear		
Ratio:		$I/(A_{rad} \cdot r_m^2)$	0,00216	[1]
Ratio:		$I/(A_{rad} \cdot r_m^2) \cdot \kappa_q$	0,00259	[1]

		q_v	q_h	q_h^*	
Deflection coefficient for bending moments:	c_v	-0,0893	0,0833	0,0640	[1]
Deflection coefficient for axial forces:	cN_v	-0,683	-0,681	-0,247	[1]
Deflection coefficient for lateral forces:	cQ_v	-0,359	0,335	0,243	[1]
Resultant deflection coefficient:	c'_v	-0,0933	0,0842	0,0652	[1]

Vertical diameter change:	Δd_v	27,2	mm
Horizontal diameter change:	Δd_h	18,8	mm
Relative vertical deformation:	δ_v	2,16	%
Allowable deflection:	all d_v	6,00	%

The deflection determined is less than the allowable deflection.

Stability proof (linear) (with maximum groundwater):

Total vertical load	q_v	80,4	kN/m²
Reduction factor for soil/traffic load:	κ_{v2}	0,86	[1]
Critical buckling load (soil/traffic load):	crit q_v	834,3	kN/m²
Partial buckling safety (soil/traffic load):	$\gamma_{buckl,qv}$	10,38	[1]
External water pressure:	p_e	25,0	kN/m²
Plus vacuum in the pipe:	p_{l^-}	0,0	kN/m²
Sytem stiffness without traffic load correction:	V_{RB}	0,0214	[1]
Input value δ_{v2} for determining κ_{a2}:	δ_{v2}	3,16	%
Predeformation reduction factor for water pressure:	κ_{r2}	0,76	[1]
Local predeformation reduction factor for water pressure:	κ_{r1}	1,00	[1]
Parameter k* (substitute for r_m/s) for determining α_D:	k*	6,210	[1]
Perforation coefficient:	α_P	7,264	[1]
Critical buckling load (external water pressure):	crit p_e	392,2	kN/m²
Partial buckling safety (external water pressure):	$\gamma_{buckl,pe}$	15,69	[1]

Buckling safety:	γ_{buckl}	6,25	[1]
Required buckling safety:	req γ_{buckl}	2,00	[1]

The buckling safety factors determined are greater than required.

Non linear stability proof (with maximum groundwater):

- n/a -

Proof for load case combination 2, Short term

Stress proof:

Calculated ultimate flexural tensile stress, soil/traffic load:	$\sigma_{,calc,BZ}$	29,9	N/mm²
Calculated ultimate flexural compr. stress, soil/traffic load:	$\sigma_{,calc,BD}$	49,9	N/mm²
Ultimate flexural tensile stress due to other loads:	$\sigma_{all,BZ}$	29,9	N/mm²
Ultimate flexural compressive stress due to other loads:	$\sigma_{all,BD}$	49,9	N/mm²

Internal:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,i}$	1,720	-4,507	2,294	N/mm²
Stress due to other loads:	$\sigma_{other,i}$	0,368	-0,339	0,915	N/mm²
Safety:	γ_{BTi}	14,32	---	9,32	[1]
Safety:	γ_{BCi}	---	10,30	---	[1]

External:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,a}$	-7,08	1,79	-8,44	N/mm²
Stress due to other loads:	$\sigma_{other,a}$	-0,53	0,72	-1,03	N/mm²
Safety:	γ_{BTe}	---	11,92	---	[1]
Safety:	γ_{BCe}	6,56	---	5,27	[1]

Required flexural tensile safety:	req γ_{BT}	2,50	[1]
Required flexural compressive safety:	req γ_{BC}	2,50	[1]

The stress safety factors determined are greater than the required factors.

Deflection proof:

Calculation method:	linear		
Ratio:	$I/(A_{rad} \cdot r_m^2)$	0,00216	[1]
Ratio:	$I/(A_{rad} \cdot r_m^2) \cdot \kappa_q$	0,00259	[1]

		q_v	q_h	q_h^*	
Deflection coefficient for bending moments:	c_v	-0,0893	0,0833	0,0640	[1]
Deflection coefficient for axial forces:	cN_v	-0,683	-0,681	-0,247	[1]
Deflection coefficient for lateral forces:	cQ_v	-0,359	0,335	0,243	[1]
Resultant deflection coefficient:	c'_v	-0,0933	0,0842	0,0652	[1]

Vertical diameter change:	Δd_v	25,4	mm
Horizontal diameter change:	Δd_h	19,0	mm
Relative vertical deformation:	δ_v	2,02	%
Allowable deflection:	all d_v	6,00	%

The deflection determined is less than the allowable deflection.

Stability proof (linear):

Total vertical load	q_v	61,0	kN/m²
Reduction factor for soil/traffic load:	κ_{v2}	0,86	[1]
Critical buckling load (soil/traffic load):	crit q_v	834,3	kN/m²

The buckling proof for water pressure does not apply, as there is neither groundwater nor a vacuum.

Buckling safety:	γ_{buckl}	13,68	[1]
Required buckling safety:	req γ_{buckl}	2,00	[1]

The buckling safety factors determined are greater than required.

Non linear stability proof:

- n/a -

Proof for load case combination 1, Long term

Stress proof (with minimum groundwater):

Calculated ultimate flexural tensile stress, soil/traffic load:	$\sigma_{,calc,BZ}$	22,2	N/mm²
Calculated ultimate flexural compr. stress, soil/traffic load:	$\sigma_{,calc,BD}$	37,1	N/mm²
Ultimate flexural tensile stress due to other loads:	$\sigma_{all,BZ}$	20,9	N/mm²
Ultimate flexural compressive stress due to other loads:	$\sigma_{all,BD}$	34,9	N/mm²

Internal:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,i}$	-0,827	-4,067	0,004	N/mm²
Stress due to other loads:	$\sigma_{other,i}$	0,192	-0,163	0,739	N/mm²
Safety:	γ_{BTi}	---	---	28,12	[1]
Safety:	γ_{BCi}	76,17	8,74	---	[1]

External:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,a}$	-5,91	-1,78	-7,88	N/mm²
Stress due to other loads:	$\sigma_{other,a}$	-0,28	0,40	-0,78	N/mm²
Safety:	γ_{BTe}	---	---	---	[1]
Safety:	γ_{BCe}	5,97	34,81	4,26	[1]

Required flexural tensile safety:	req γ_{BT}	2,50	[1]
Required flexural compressive safety:	req γ_{BC}	2,50	[1]

The stress safety factors determined are greater than the required factors.

Stress proof (with maximum groundwater):

Calculated ultimate flexural tensile stress, soil/traffic load:	$\sigma_{,calc,BZ}$	22,4	N/mm²
Calculated ultimate flexural compr. stress, soil/traffic load:	$\sigma_{,calc,BD}$	37,3	N/mm²
Ultimate flexural tensile stress due to other loads:	$\sigma_{all,BZ}$	20,9	N/mm²
Ultimate flexural compressive stress due to other loads:	$\sigma_{all,BD}$	34,9	N/mm²

Internal:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,i}$	-0,578	-3,692	0,164	N/mm²
Stress due to other loads:	$\sigma_{other,i}$	-0,840	-1,195	-0,293	N/mm²
Safety:	γ_{BTi}	---	---	---	[1]
Safety:	γ_{BCi}	25,27	7,51	932,15	[1]

External:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,a}$	-5,45	-1,48	-7,21	N/mm²
Stress due to other loads:	$\sigma_{other,a}$	-1,22	-0,54	-1,73	N/mm²
Safety:	γ_{BTe}	---	---	---	[1]
Safety:	γ_{BCe}	5,52	18,12	4,12	[1]

Required flexural tensile safety:	req γ_{BT}	2,50	[1]
Required flexural compressive safety:	req γ_{BC}	2,50	[1]

The stress safety factors determined are greater than the required factors.

Deflection proof (with minimum groundwater):

Calculation method:		linear			
Ratio:		$I/(A_{rad} \cdot r_m^2)$	0,00216	[1]	
Ratio:		$I/(A_{rad} \cdot r_m^2) \cdot \kappa_q$	0,00259	[1]	
		q_v	q_h	q_h^*	
Deflection coefficient for bending moments:	c_v	-0,0893	0,0833	0,0640	[1]
Deflection coefficient for axial forces:	cN_v	-0,683	-0,681	-0,247	[1]
Deflection coefficient for lateral forces:	cQ_v	-0,359	0,335	0,243	[1]
Resultant deflection coefficient:	c'_v	-0,0933	0,0842	0,0652	[1]

Vertical diameter change:	Δd_v	49,8	mm
Horizontal diameter change:	Δd_h	22,3	mm
Relative vertical deformation:	δ_v	3,96	%
Allowable deflection:	all d_v	6,00	%

The deflection determined is less than the allowable deflection.

Deflection proof (with maximum groundwater):

Calculation method:		linear			
Ratio:		$I/(A_{rad} \cdot r_m^2)$	0,00216	[1]	
Ratio:		$I/(A_{rad} \cdot r_m^2) \cdot \kappa_q$	0,00259	[1]	
		q_v	q_h	q_h^*	
Deflection coefficient for bending moments:	c_v	-0,0893	0,0833	0,0640	[1]
Deflection coefficient for axial forces:	cN_v	-0,683	-0,681	-0,247	[1]
Deflection coefficient for lateral forces:	cQ_v	-0,359	0,335	0,243	[1]
Resultant deflection coefficient:	c'_v	-0,0933	0,0842	0,0652	[1]

Vertical diameter change:	Δd_v	44,8	mm
Horizontal diameter change:	Δd_h	21,0	mm
Relative vertical deformation:	δ_v	3,56	%
Allowable deflection:	all d_v	6,00	%

The deflection determined is less than the allowable deflection.

Stability proof (linear) (with maximum groundwater):

Total vertical load	q_v	78,8	kN/m²
Reduction factor for soil/traffic load:	κ_{v2}	0,87	[1]
Critical buckling load (soil/traffic load):	crit q_v	507,8	kN/m²
Partial buckling safety (soil/traffic load):	$\gamma_{buckl,qv}$	6,45	[1]
External water pressure:	p_e	25,0	kN/m²
Plus vacuum in the pipe:	p_i-	0,0	kN/m²
Sytem stiffness without traffic load correction:	V_{RB}	0,0052	[1]
Input value δ_{v2} for determining κ_{a2}:	δ_{v2}	4,56	%
Predeformation reduction factor for water pressure:	κ_{r2}	0,78	[1]
Local predeformation reduction factor for water pressure:	κ_{r1}	1,00	[1]
Parameter k* (substitute for r_m/s) for determining α_D:	k*	6,210	[1]
Perforation coefficient:	α_P	9,670	[1]
Critical buckling load (external water pressure):	crit p_e	130,0	kN/m²
Partial buckling safety (external water pressure):	$\gamma_{buckl,pe}$	5,20	[1]

Buckling safety:	γ_{buckl}	2,88	[1]
Required buckling safety:	req γ_{buckl}	2,00	[1]

The buckling safety factors determined are greater than required.

Non linear stability proof (with maximum groundwater):

- n/a -

Proof for load case combination 2, Long term

Stress proof:

Calculated ultimate flexural tensile stress, soil/traffic load:	$\sigma_{,calc,BZ}$	27,6	N/mm²
Calculated ultimate flexural compr. stress, soil/traffic load:	$\sigma_{,calc,BD}$	46,0	N/mm²
Ultimate flexural tensile stress due to other loads:	$\sigma_{all,BZ}$	20,9	N/mm²
Ultimate flexural compressive stress due to other loads:	$\sigma_{all,BD}$	34,9	N/mm²

Internal:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,i}$	1,302	-4,087	1,877	N/mm²
Stress due to other loads:	$\sigma_{other,i}$	0,192	-0,163	0,739	N/mm²
Safety:	γ_{BTi}	17,71	---	9,66	[1]
Safety:	γ_{BCi}	---	10,69	---	[1]

External:		Crown	Springline	Bottom	
Stress due to soil and traffic loads:	$\sigma_{qv,qh,qh^*,a}$	-6,48	1,05	-7,84	N/mm²
Stress due to other loads:	$\sigma_{other,a}$	-0,28	0,40	-0,78	N/mm²
Safety:	γ_{BTe}	---	17,45	---	[1]
Safety:	γ_{BCe}	6,72	---	5,19	[1]

Required flexural tensile safety:	req γ_{BT}	2,50	[1]
Required flexural compressive safety:	req γ_{BC}	2,50	[1]

The stress safety factors determined are greater than the required factors.

Deflection proof:

Calculation method:	linear		
Ratio:	$I/(A_{rad} \cdot r_m^2)$	0,00216	[1]
Ratio:	$I/(A_{rad} \cdot r_m^2) \cdot \kappa_q$	0,00259	[1]

		q_v	q_h	q_h^*	
Deflection coefficient for bending moments:	c_v	-0,0893	0,0833	0,0640	[1]
Deflection coefficient for axial forces:	cN_v	-0,683	-0,681	-0,247	[1]
Deflection coefficient for lateral forces:	cQ_v	-0,359	0,335	0,243	[1]
Resultant deflection coefficient:	c'_v	-0,0933	0,0842	0,0652	[1]

Vertical diameter change:	Δd_v	28,1	mm
Horizontal diameter change:	Δd_h	19,9	mm
Relative vertical deformation:	δ_v	2,23	%
Allowable deflection:	all d_v	6,00	%

The deflection determined is less than the allowable deflection.

Stability proof (linear):

Total vertical load	q_v	61,0	kN/m²
Reduction factor for soil/traffic load:	κ_{v2}	0,87	[1]
Critical buckling load (soil/traffic load):	crit q_v	749,1	kN/m²

The buckling proof for water pressure does not apply, as there is neither groundwater nor a vacuum.

Buckling safety:	γ_{buckl}	12,29	[1]
Required buckling safety:	req γ_{buckl}	2,00	[1]

The buckling safety factors determined are greater than required.

Non linear stability proof:

- n/a -