EUROPEAN NO•DIG 2023 Conference ITALY

DWA-A 143-2 Static Calculation for the Rehabilitation of Drains and Sewers

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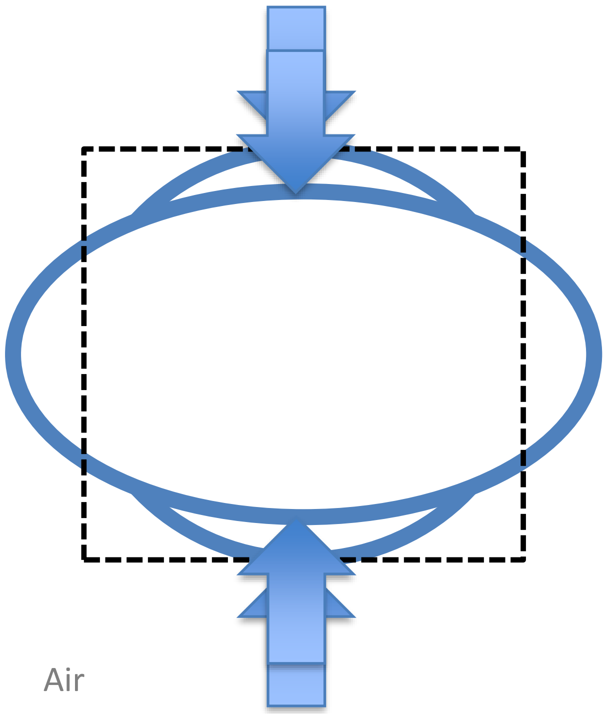
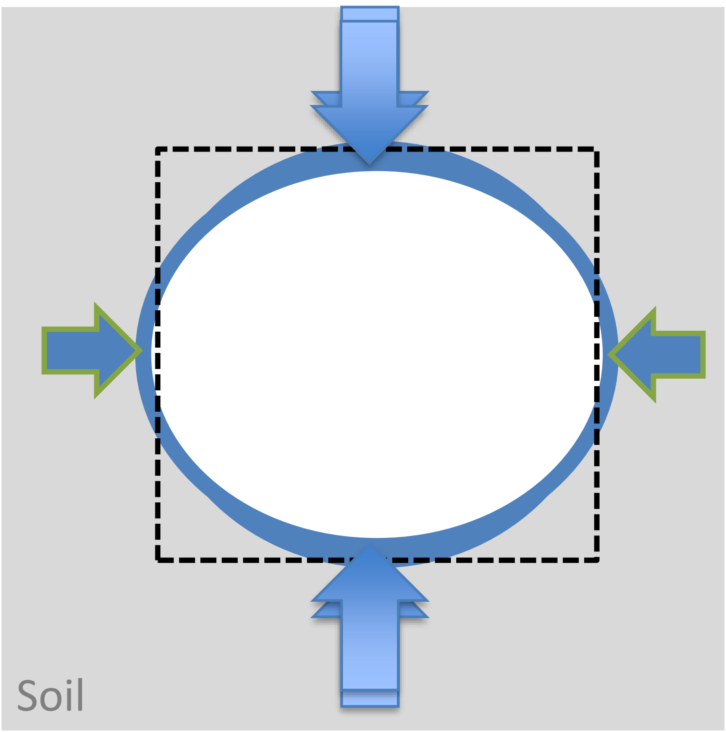
25th May 2023

Free pipe and buried pipe





ATV-DVWK-A 127: Soil

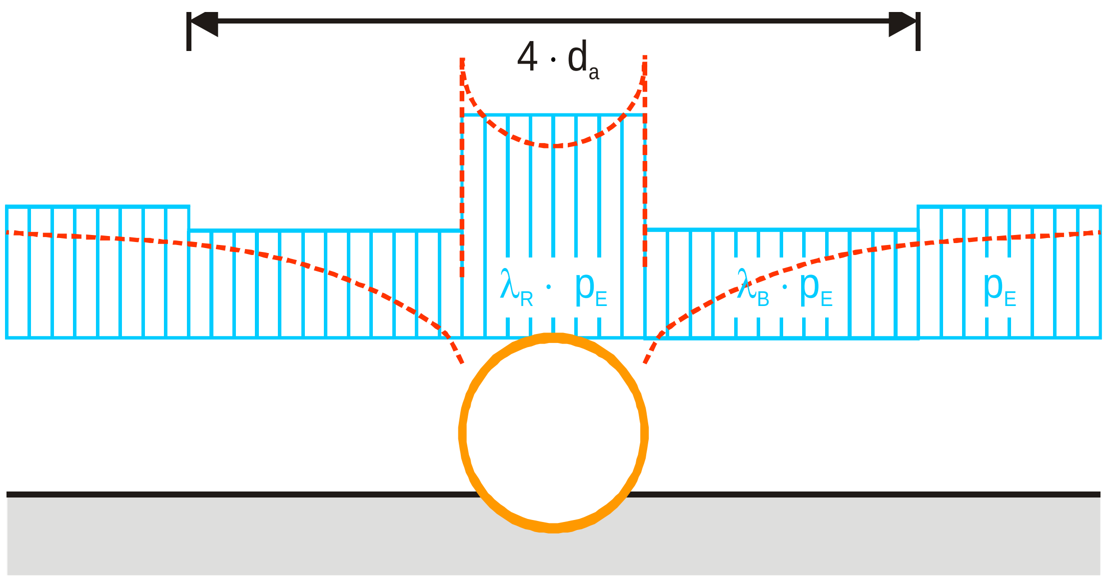
- Great importance for structural calculation
- For a solid rock, the pipe only prevents leakage (solid rock is self-supported)
- Poor soil in bedding zone combined with great coverage or heavy traffic breaks the strongest pipe
- Soil types according to ATV-DVWK-A 127
- Interpretation of the geological survey sometimes doubles the efforts for the structural calculation
- Soil zones around pipe and Young’s modulus accordingly

Table 1: Types of soil

Group	Spec. gravity	Spec. Gravity under buoyancy	Internal friction angle	Elasticity modulus E_S in N/mm² with degrees of compaction D_{Pr} in %						Exponent in Eqn. (3.02) *[Amended]*	Reduction factor for creep
	γ_S kN/m³	γ_S' kN/m³	φ' °	85	90	92	95	97	100	Z -	f_1 -
G1	20	11	35	2[2)]	6	9	16	23	40	0.4	1.0
G2	20	11	30	1.2	3	4	8	11	20	0.5	1.0
G3	20	10	25	0.8	2	3	5	8	13	0.6	0.8
G4	20	10	20	0.6	1.5	2	4	6	10	0.7	0.5

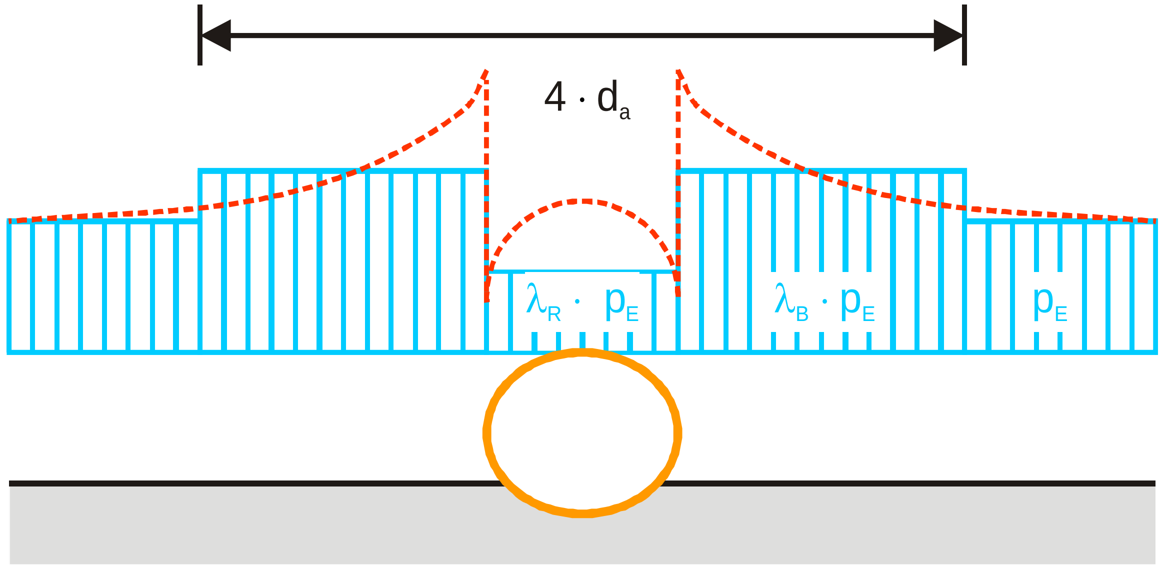
ATV-DVWK-A 127: Rigid Pipe-Soil-System stiffness $V_{RB} = S_R / S_{Bh}$

- $V_{RB} > 1$ → rigid Pipe-Soil-System (PSS)
- S_R – Pipe stiffness, S_{Bh} – horizontal bedding stiffness of the soil
- Concentration factor λ_R depends on bedding, stiffness ratio etc.
- Concrete, reinforced concrete and stoneware pipes → always rigid PSS



ATV-DVWK-A 127: Flexible Pipe-Soil-System stiffness $V_{RB} = S_R / S_{Bh}$

- $V_{RB} \leq 1$ → flexible Pipe-Soil-System
- The pipe deforms enough to transmit the greater part of the loads on the nearby soil but only in the usability tolerance limits
- Rigidity of the PSS of thermoplastic, duroplastic and even metal pipes depend on the system stiffness



DWA-A143-2: General Design Form

- Semi-probabilistic partial safety concept
- Stress and stability design
  - S_D Design value of the influences
    $S_D = \Sigma$ (Influences x Partial safety factors γ_F)
  - Design value of the material resistance
    R_D = Material strength /
    Partial safety factor for the specific material γ_M

$$\frac{S_d}{R_d} \leq 1$$

- Deformation design
  - Characteristic loads $\gamma_F = 1$
  - Characteristic material resistance $\gamma_M = 1$

DWA-A143-2: Partial safety coefficients γ_F for influences

• Permanent loads (Dead load, Earth loads, Surface loads, etc.)	$\gamma_F = 1.35$
• Variable loads (Traffic loads except road traffic load, Groundwater)	$\gamma_F = 1.50$
• Road traffic loads	$\gamma_F = 1.35$
• Short term floodwater	$\gamma_F = 1.10$
• Internal pressure (including pressure surge)	$\gamma_F = 1.50$
• Inspection pressure	$\gamma_F = 1.20$
• Temperature change	$\gamma_F = 1.10$
• Imposed deformations	$\gamma_F = 1.10$

DWA-A143-2: Partial safety coefficients γ_M for material resistance

- Plastic liners, hardened on site $\gamma_M = 1.35$
- Pre-fabricated plastic liners (Extrusion or similar) $\gamma_M = 1.25$
- Cement liner $\gamma_M = 1.50$
- Stainless steel $\gamma_M = 1.15$
- Resistance with a favourable effect (e.g., Imposed liner deformations at HPC III) $\gamma_M = 1.00$
- Concrete and vitrified clay host pipes for the proof of pressure zones (eq. 102) $\gamma_M = 1.50$

Coefficients for combinations ψ

- Temperature change combined with groundwater $\psi = 0.7$
- Actual groundwater combined with earth and traffic loads $\psi = 0.9$
- Replacement load for groundwater combined with earth and traffic loads $\psi = 0.7$

DWA-A143-2: Imperfections for circular profiles

Local imperfection

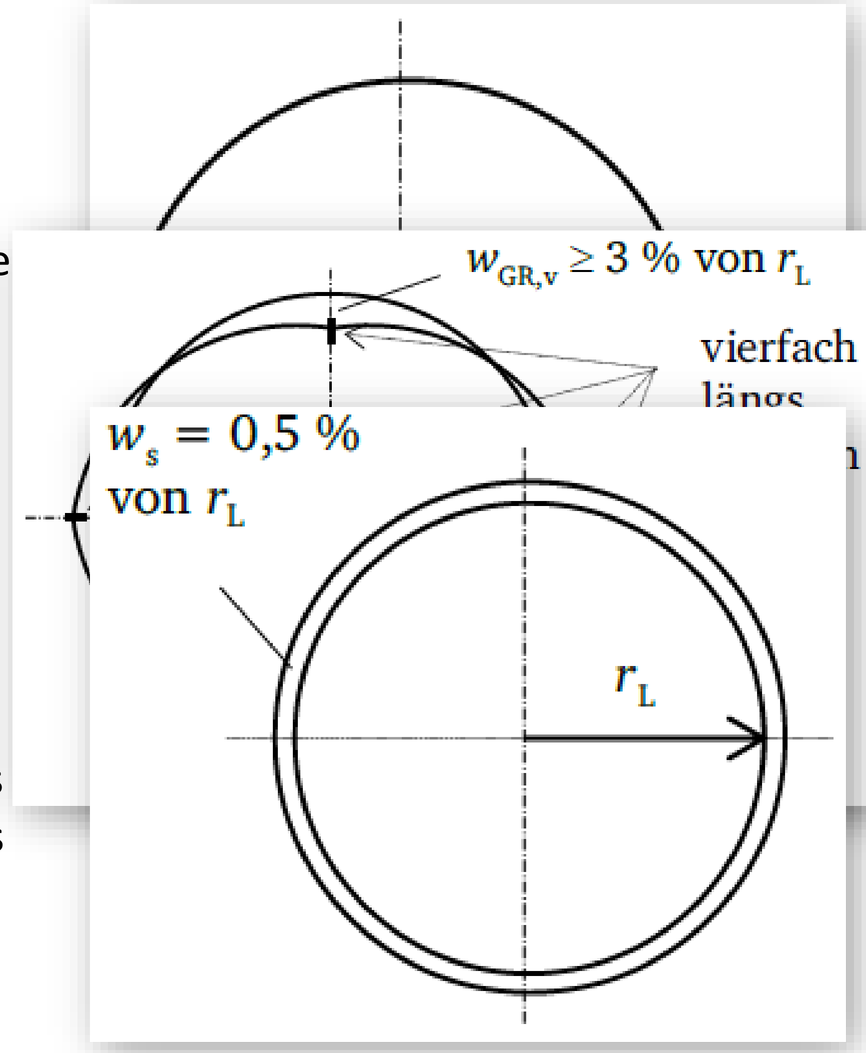
- Consider deformations in the host pipe during the installation of the liner as well as the abbreviation from the planned trace
- Consider structural imperfections (local decrease of stiffness and/or wall-thickness)
- Is required in the calculation to trigger the decisive buckling case

Ovalisation

- Is the form that host pipe takes after its cracked in crown, invert and springlines

Annular gap

- Occurs through shrinking of the resin in the liner or shrinking of the filling material



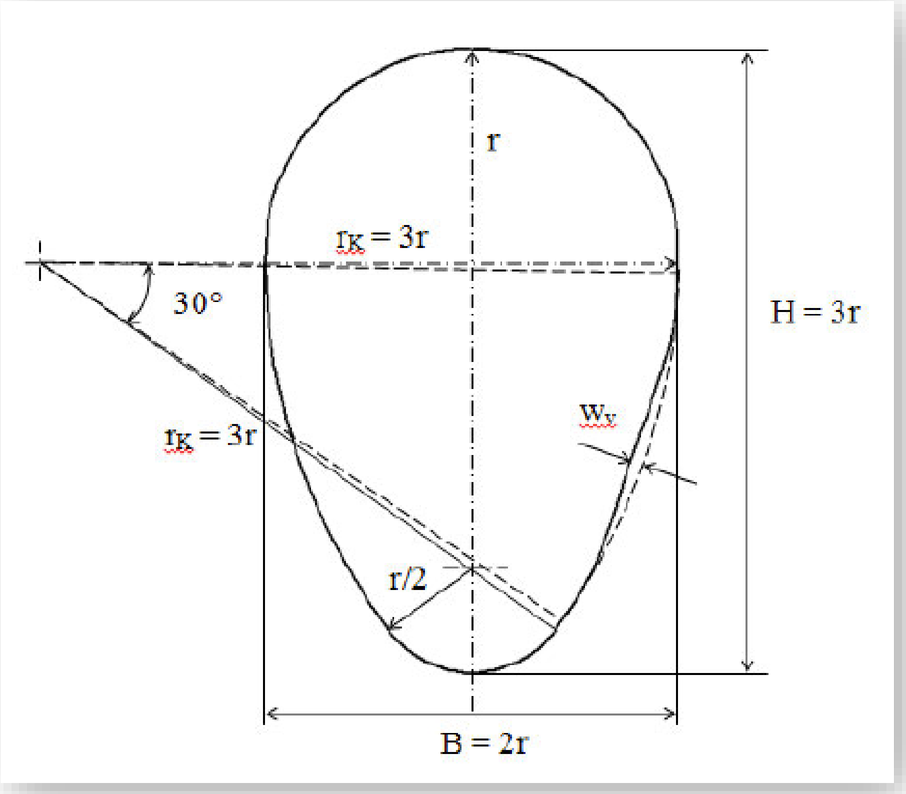
DWA-A143-2: Imperfections for oval (egg-shaped) profile

- Local deformation on the long side
- Four hinge deformation (ovalisation) inwards
- Local imperfection results as

  $\boldsymbol{\omega_L} = \omega_L + \omega_{GRV}/10 =$

  $= (0{,}5\% + 3{,}0\%/10) \times r_K$

  $\boldsymbol{\omega_L = 0.8\%\ r_K}$
- For masoned profiles $\omega_L = 1\ \%$
- Annular gap as a constant degree of shrinkage of $\varepsilon = 0{,}4\ \%$ which corresponds a gap of $0{,}4\% \times r_K$ in springline and $0{,}6\% \times r_C$ in crown



DWA-A143-2: Minimal required imperfections

Circular profile

Method	C.I.P.P.	Back-formed	Single pipe	Wounded without gap	Wounded	Pinched
Local imperfection	≥ 2%	≥ 2%	≥ 1%	≥ 1,5%	≥ 1%	≥ 2%
Ovalisation (HPC II,III)	≥ 3%	≥ 3%	0%	≥ 3%	0%	≥ 3%
Annular gap	≥ 0,5%	≥ 2%	≥ 1-2 mm	≥ 2	Material dependent	≥ 0.12%

Egg-shaped profile

	Non masoned host pipe	Masoned host pipe
Local imperfection	≥ 0,5% (r_K) +ω_{grv}/10	≥ 1% (r_K) + ω_{grv}/10
Ovalization (II,III)*	≥ 3% (crown radius)*	
Annular gap	Degree of shrinkage ≥ 0,4%	

DWA-A143-2: Host pipe condition I

Host pipe alone is capable of bearing loads

- Leaks in connections
- No cracks (except capillary cracks)

Imperfections

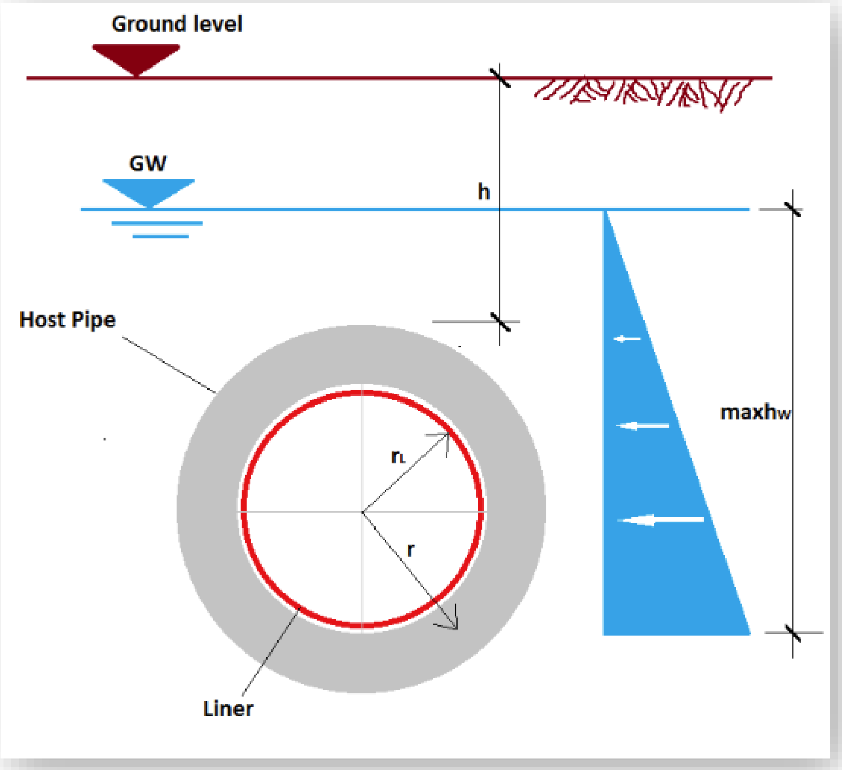
- Local imperfection
- Annular gap

Influence

- Groundwater pressure

Required proofs

- Stresses and deformations
- Buckling (Stability)



DWA-A143-2: Host pipe condition II

Host pipe-soil-system is capable of bearing loads

- Longitudinal cracks, minor pipe deformation $\delta_V < 6\ \%$
- Functionality of the lateral bedding proven through soil boring

Imperfections

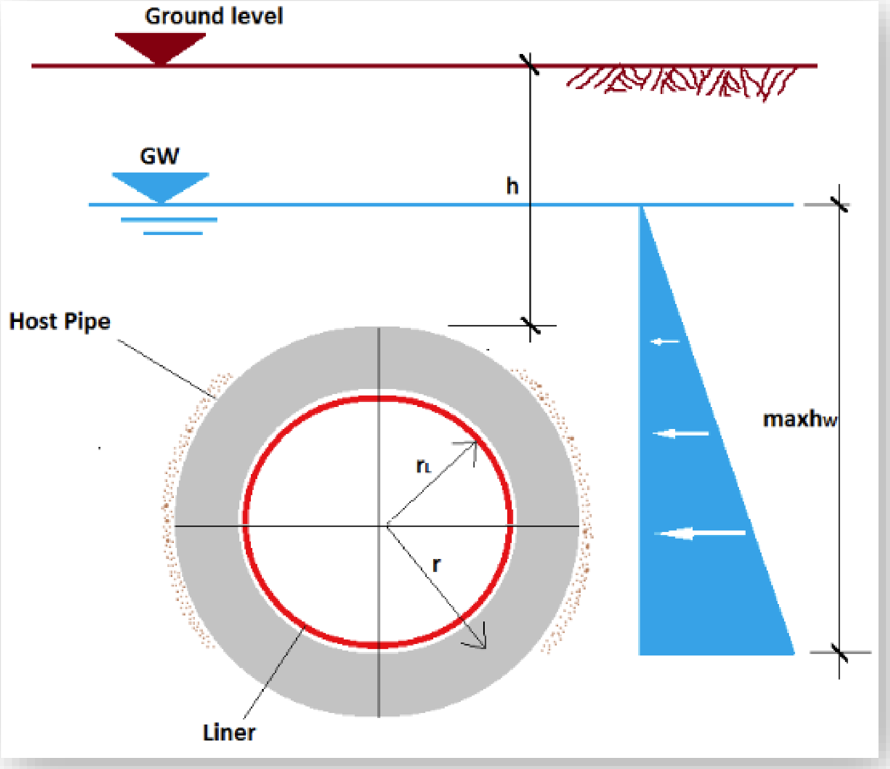
- Local imperfection
- Ovalisation
- Annular gap

Influence

- Groundwater pressure

Required proofs

- Stresses and deformations
- Buckling (Stability)



DWA-A143-2: Host pipe condition III

Host pipe-soil system no longer capable of bearing loads in the long-term

- Longitudinal cracks, significant pipe deformation $\delta_V \geq 6$ %

Imperfections

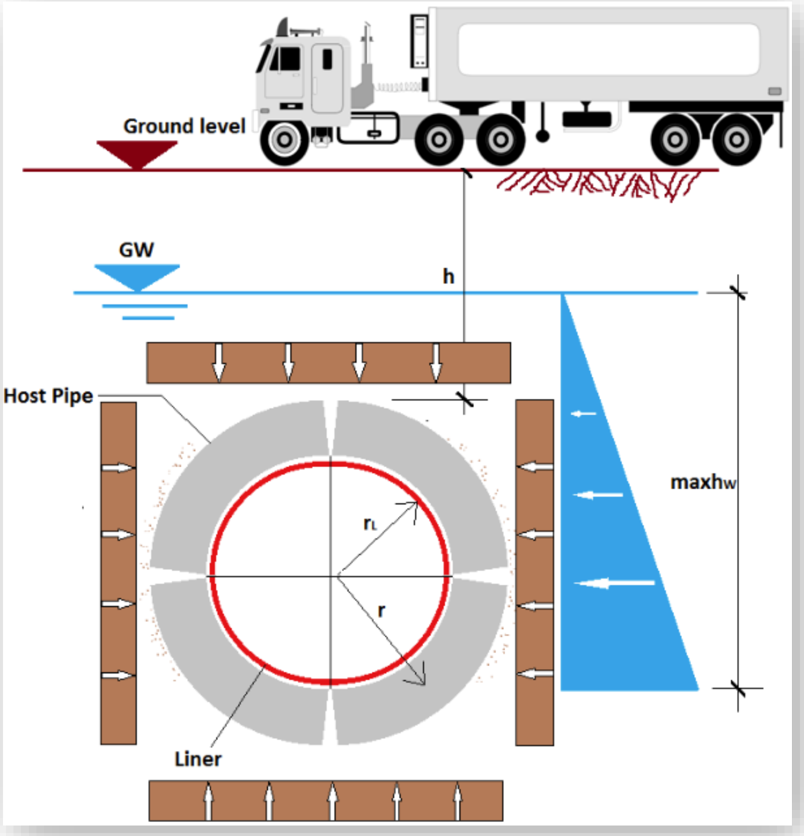
- As for HPC II

Influence

- Groundwater pressure
- Earth and traffic loads

Required proofs

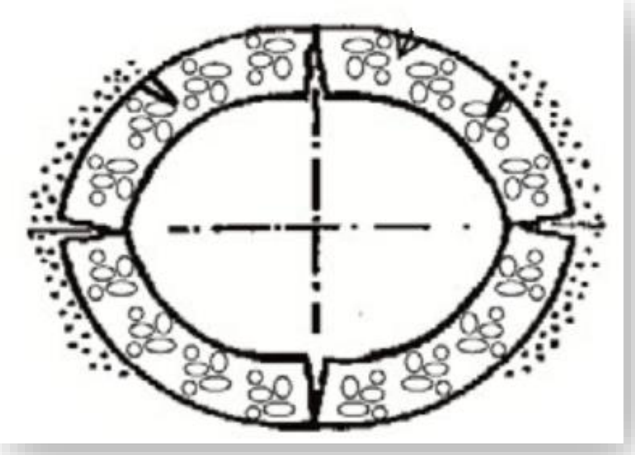
- Stresses and deformations
- Buckling (Stability)
- Interaction proof



DWA-A143-2: Host pipe condition IIIa

As HPC III however

- The load transmission in the host pipe pressure zones is not possible due to insufficient strength of host pipe material
- Host pipe is cracked in fragments not in four joints
- HPC IIIa has an informative character only and finds place in appendix K of the DWA-A 143 part 2
- Liner is calculated as buried pipe (elastically bedded ring) according to the ATV-DVWK-A 127



DWA-A143-2: Host pipe condition II or III?

	Determination point	HPC II	HPC III
1	Ovalization $\boldsymbol{\omega}_{\mathbf{GR,V}}$	$\leq 6\,\%$	> 6 %
2	Cover depth **h**	High	Low[1]
3	Traffic load influence	Low	High
4	Load increase in time (foundations, surface load)	No	Yes
5	Plaster marks are opening	No	Yes
7	Cavity formation in soil due to infiltration	No	Yes

1) Note: cover depth
h < 1m and h < da for road traffic loads
h < 1.5 m under railway loads

DWA-A143-2: Eccentricity

HPC III only

- Distance of the rotation point (crown joint) to the mid-axis (the better the host pipe, the higher the value)
- In standard case e_G = 0,35

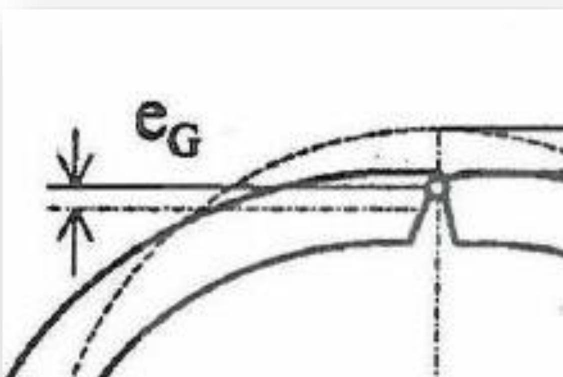
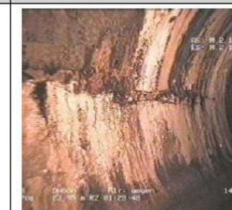
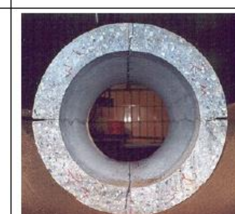


Tabelle 14: Wahl der Gelenkexzentrizität e_G in Abhängigkeit von der Altrohrdruckzone

Zustand der Altrohrdruckzone im Kämpfer	Bezogene Gelenkexzentrizität e_G/t	Zugehörende bezogene Druckzonenbreite b_D/t siehe Gl. (101)	Beispiel
Starke Schädigung • sichtbare Abplatzungen • geringe Druckfestigkeit • erhebliche Korrosion	≤ 0,25	≥ 0,67	
Normaler Zustand • keine oder nur geringe Abplatzungen • höhere Druckfestigkeit • geringe Korrosion = Regelfall	0,35	0,40	
Guter Zustand: • keine Abplatzungen • hohe Druckfestigkeit • keine Korrosion • neuwertiges Rohr	≤ 0,45	≥ 0,13	

DWA-A143-2: Traffic loads

Road traffic loads

- LM 1 according to DIN EN 1991-2
- Ground stresses due to LM 1 in a diagram form depending on
  - Host pipe length
  - Cover depth (0.5 – 10 m)
  - Diameter

Railway traffic loads

- LM 71 according to DIN EN 1991-2
- Ground stresses due to LM 71 in a diagram form for $h_E > 1.1$ m

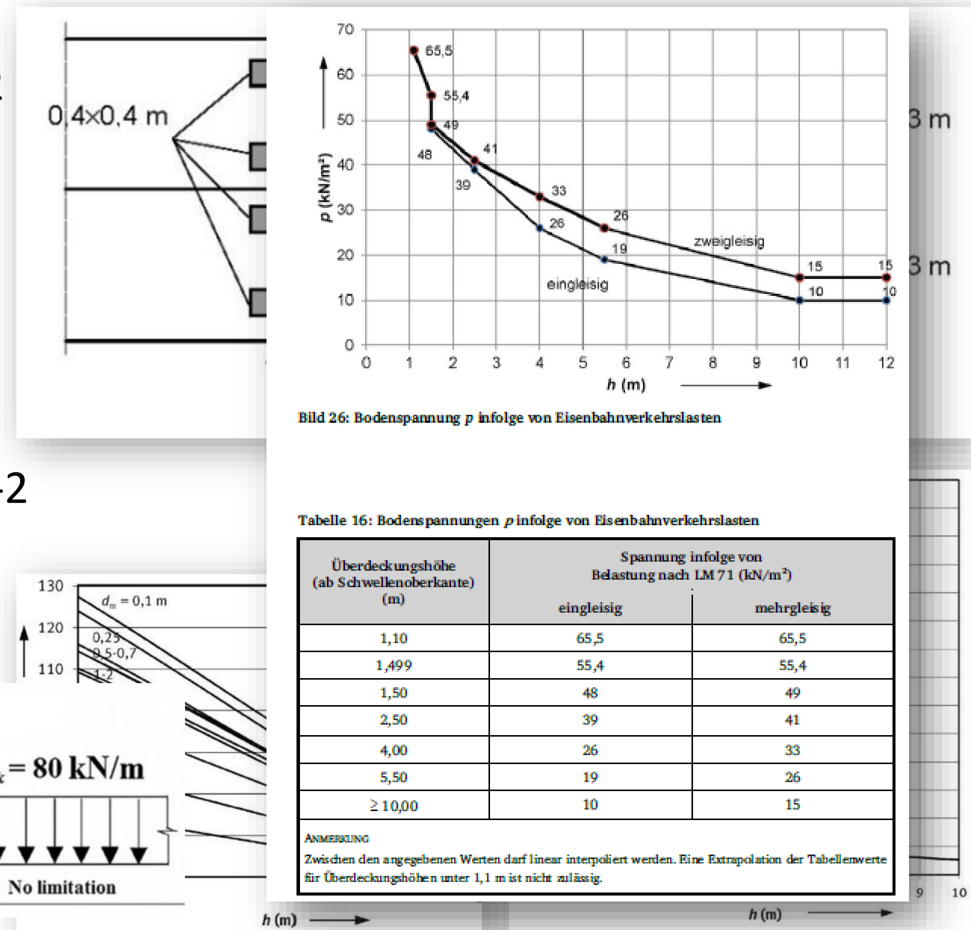
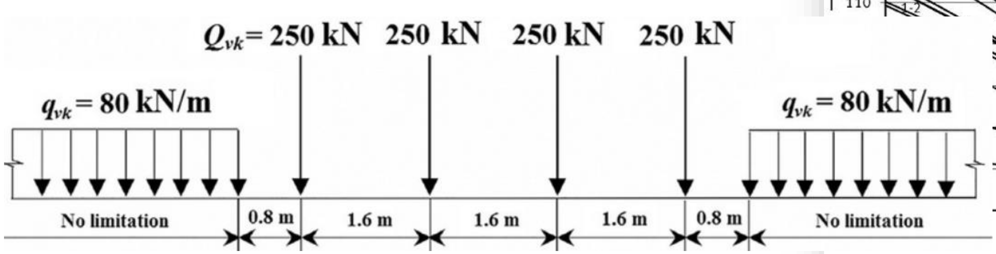


Bild 26: Bodenspannung p infolge von Eisenbahnverkehrslasten

Tabelle 16: Bodenspannungen p infolge von Eisenbahnverkehrslasten

Überdeckungshöhe (ab Schwellenoberkante) (m)	Spannung infolge von Belastung nach LM 71 (kN/m²) eingleisig	mehrgleisig
1,10	65,5	65,5
1,499	55,4	55,4
1,50	48	49
2,50	39	41
4,00	26	33
5,50	19	26
≥ 10,00	10	15

ANMERKUNG
Zwischen den angegebenen Werten darf linear interpoliert werden. Eine Extrapolation der Tabellenwerte für Überdeckungshöhen unter 1,1 m ist nicht zulässig.



DWA-A143-2: Verifications

Stability

- Stability proof using the Kappa diagrams
- Stability proof as stress proof according to the II order theory with γ-fold loads and a design E-Modulus considering the imperfections

Stress

- Stress proof is conducted using cross-section coefficients for moments and normal forces in the appendix of the DWA-A 143-2 set of rules
- Design loads must be applied; In HPC III partial safety factor for material must be alternatively set to $\gamma_M = 1$ to consider constraint effect
- Proof of soil limit stress - preventing soil fracture

Deformations

- Characteristic loads and material properties must be applied
- Total deformation is limited to 10% (elastic + imperfections)
- Elastic deformations are limited to
  - $\delta_{v,el} \leq 3\%$ for water pressure
  - $\delta_{v,el} \leq 6\%$ for earth and traffic loads
  - $\delta_{v,el} \leq 2\%$ or 10 mm for railway loads (DB)

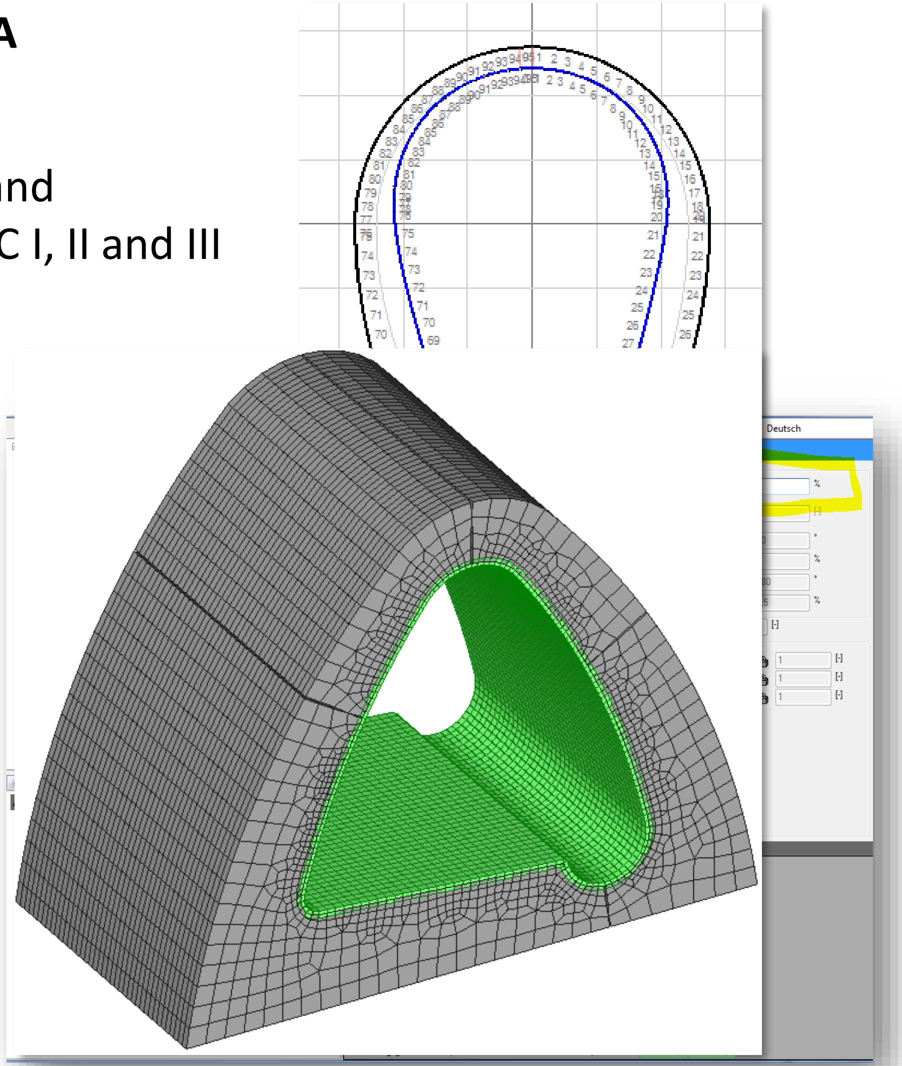
DWA-A143-2: Software solution and FEA

IngSoft EasyPipe A143-2 Module

- For circular and egg-shaped profiles and arbitrary rehabilitation method in HPC I, II and III
- Nonlinear Finite Element Calculation according to the II order theory

FEA for special profiles

- For special shape profiles general FEA software should be applied
- Femap with NX Nastran, Ansys



Thank you for your attention

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