# Structural analysis

Description: GRP pipes DN 200
PN01
SN 10.000

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# 2 Statics according to ATV-DVWK-A 127, 3rd edition: Cevovod 1, minimalni nadsloj 0,8 m

| | |
|---|---|
| Caption of this part of the calculation: | Cevovod 1, minimalni nadsloj 0,8 m |
| Notes: | DN 200<br>PN01<br>SN 10.000<br>Kut iskopa 90° |

| | |
|---|---|
| Kind of calculation: | Nominal stiffness |
| Add sketch to print: | Yes |

## 2.1 Input

### 2.1.1 Safety factors

| | |
|---|---|
| Safety class: | A (normal case) |
| Safety stability according to table 13: | Without predeformation (2.5 / 2.0) |
| Allowable deflection: | 6% (standard) |
| Treatment of internal pressure: | In accordance with Footnote 39 in ATV-DVWK-A 127 |
| Lower safety factors for flexural compression: | No (ATV-DVWK-A 127) |
| Proof for not predominantly static loading: | According to standard |
| Consideration of dyn pvh*: | According to standard |
| Consideration of Type A 'predeformation' in the deformation proof: | Yes |

### 2.1.2 Soil

| | | | |
|---|---|---|---|
| Soil group backfill: | G1 | | |
| Calculation E1: | Table 8 (A127) | | |
| Soil group pipe zone: | G1 | | |
| Calculation E20: | Table 8 (A127) | | |
| Soil group native soil: | G3 | | |
| Calculation E3: | Compression ratio | | |
| Compression ratio E3: | $D_{Pr,E3}$ | 90.0 | % |
| E4 = 10 · E1: | Yes | | |
| Application of silo theory: | Automatic | | |

### 2.1.3 Load

| | | | |
|---|---|---|---|
| Cover depth: | $h$ | 0.80 | m |
| Minimum groundwater level above pipe bed: | $h_{W,min}$ | 0.00 | m |
| Maximum groundwater level above pipe bed: | $h_{W,max}$ | 0.00 | m |
| Soil density: | $\gamma$ | 20.0 | kN/m³ |
| Additional surface load: | $p_0$ | 0.0 | kN/m² |
| Inner pressure, short term: | $P_{I,K}$ | 0.00 | bar |
| Inner pressure, long term: | $P_{I,L}$ | 0.00 | bar |
| Water fill (e.g. damming channel): | Yes | | |
| Density of medium: | $\gamma_F$ | 10.0 | kN/m³ |
| Input special-purpose vehicle: | No | | |
| Traffic load: | HGV 60 | | |
| Including horizontal loads due to traffic in the fatigue proof: | $\alpha_{qhT,dyn}$ | 0.00 | % |

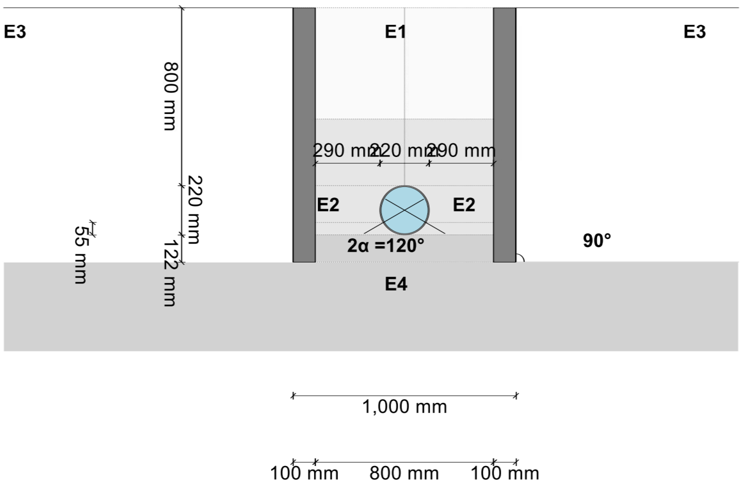
### 2.1.4 Installation

| | | | |
|---|---|---|---|
| Installation: | Trench | | |
| Trench width at pipe crown level: | b | 1.00 | m |
| Check minimum trench width: | Yes | | |
| Automatic consideration of bedding layer: | Yes | | |
| Slope angle: | ß | 90 | ° |
| Cover condition: | A2 | | |
| Installation condition: | B2 | | |
| Lining below pipe taken into account as per ATV Work Group 1.5.5 report.: | No | | |
| Thickness of bulkhead: | $b_S$ | 0.10 | m |
| Type of bedding: | Loose | | |
| Bedding angle: | 120° | | |
| Calculate bedding automatically: | Yes | | |
| Set lower height base: | No | | |
| Total height of base: | $h_S$ | 0.00 | m |

### 2.1.5 Pipe with nominal stiffness

| | | | |
|---|---|---|---|
| Pipe chosen from datebase: | No | | |
| Choice of input: | Do - s | | |
| Outer diameter: | $d_a$ | 220 | mm |
| Wall thickness: | t | 6.0 | mm |
| Local predeformation: | $\delta_{v,lokal}$ | 0.0 | % |
| Nominal stiffness: | SN | 10,000 | N/m² |
| Nominal pressure: | PN | 1.0 | bar |
| Relative failure strain according to standard: | Yes | | |
| Creep ratio: | $f_{Kriech}$ | 2.00 | [-] |
| Reduction factor due to temperature effect: | $A_{1,Temp}$ | 1.00 | [-] |
| Reduction factor due to media attack: | $A_{2,Medium}$ | 1.00 | [-] |
| Reduction factor due to dynamic loading: | $A_{3,dyn}$ | 1.00 | [-] |
| Specific gravity: | $\gamma_R$ | 18.00 | kN/m³ |
| Poissons ratio: | v | 0.30 | [-] |
| Input of ultimate hoop tensile stress: | No | | |
| Ultimate strain tensile strength according to standard: | Yes | | |
| Amplitude with 2·10^6 tests is known: | Yes | | |
| Amplitude with 2·10^6 tests: | $2\sigma_{a,2E6}$ | 39.00 | N/mm² |
| Amplitude with 1·10^8 tests is known: | Yes | | |
| Amplitude of the pipe with 1·10^8 tests: | $2\sigma_{a,1E8}$ | 24.00 | N/mm² |

**Traffic load: HGV 60**



## 2.2 Results

### 2.2.1 Minimum trench width according to DIN EN 1610:2015-12

The minimum trench width at trench sole level according DIN EN 1610 is met.

### 2.2.2 Section forces

| | | | |
|---|---|---|---|
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 75.02 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 37.512 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because SBh < 6 N/mm².

| | | | |
|---|---|---|---|
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 75.02 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 37.512 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because SBh < 6 N/mm².

### 2.2.3 Short term load case

<u>2.2.3.1 Strain proof</u>

| | | crown | springline | invert | |
|---|---|---|---|---|---|
| Safety coefficient outside | γ | -7.548 | 14.107 | -6.297 | [-] |
| Safety coefficient Inside | γ | 8.480 | -9.378 | 6.958 | [-] |

(Safety coefficients for flexural compressive stress are marked with a minus sign)

| | | | |
|---|---|---|---|
| Required safety coifficient, bending tensile stress: | erf $\gamma_{RBZ}$ | 2.00 | [-] |
| Required safety coifficient, bending compressive stress: | erf $\gamma_{RBD}$ | 2.00 | [-] |

All calculated safety coefficients of the strain proof are sufficient.

<u>2.2.3.2 Deformation proof</u>

| | | | |
|---|---|---|---|
| Total vertical deformation (Type A + Type B): | $\delta_{V,Ges}$ | 3.52 | % |
| Allowable deflection: | zul $\delta_V$ | 6.00 | % |

The deflection determined is less than the allowable deflection.

### 2.2.4 Long term load case

<u>2.2.4.1 Strain proof</u>

| | | crown | springline | invert | |
|---|---|---|---|---|---|
| Safety coefficient outside | γ | -6.676 | 13.130 | -5.465 | [-] |
| Safety coefficient Inside | γ | 7.579 | -8.480 | 6.059 | [-] |

(Safety coefficients for flexural compressive stress are marked with a minus sign)

| | | | |
|---|---|---|---|
| Required safety coifficient, bending tensile stress: | erf $\gamma_{RBZ}$ | 2.00 | [-] |
| Required safety coifficient, bending compressive stress: | erf $\gamma_{RBD}$ | 2.00 | [-] |

All calculated safety coefficients of the strain proof are sufficient.

<u>2.2.4.2 Deformation proof</u>

| | | | |
|---|---|---|---|
| Total vertical deformation (Type A + Type B): | $\delta_{V,Ges}$ | 3.59 | % |
| Allowable deflection: | zul $\delta_V$ | 6.00 | % |

The deflection determined is less than the allowable deflection.

2.2.4.3 Stabilty proof radial, linear

**Earth and traffic loads**

| | | | |
|---|---|---|---|
| Critical vertical total load: | krit $q_v$ | 885.2 | kN/m² |
| Total vertical load: | $q_v$ | 89.02 | kN/m² |
| Safety stability, radial: | $\gamma_{Stab,rad}$ | 9.94 | [-] |
| Required safety coifficient, instability (buckling): | erf $\gamma_{stab}$ | 2.50 | [-] |

The buckling proof is fulfilled.

2.2.4.4 stability proof, nonlinear

The nonlinear stability proof is not applicable because of VRB > 1.0 (rigid pipe) or relative vertical deformation < 6%.

2.2.4.5 Proof of safety against failure with not predominantly static loading

| | | | |
|---|---|---|---|
| Amplitude for 6·10^6 load cycles: | $2\sigma_{a,2E6}$ | 39.000 | N/mm² |
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 75.02 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 37.512 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because SBh < 6 N/mm².

| | | | | | |
|---|---|---|---|---|---|
| Inside | | | | | |
| Dynamic stress portion external | dyn $\sigma_{pV}$ | 19.050 | -19.992 | 20.034 | N/mm² |
| Safety coefficient external: | dyn $\gamma$ | 2.047 | --- | 1.947 | [-] |
| Required safety coefficient: | | | erf $\gamma$ | 1.000 | [-] |
| outside | | | | | |
| Dynamic stress portion external | dyn $\sigma_{pV}$ | -18.315 | 17.945 | -19.335 | N/mm² |
| Safety coefficient external: | dyn $\gamma$ | --- | 2.173 | --- | [-] |
| Required safety coefficient: | | | erf $\gamma$ | 1.000 | [-] |

The determined safety coefficients are sufficient.

All necessary proofs are ok.

# 3 Statics according to ATV-DVWK-A 127, 3rd edition: Cevovod 1, maksimalni nadsloj 4 m

| | |
|---|---|
| Caption of this part of the calculation: | Cevovod 1, maksimalni nadsloj 4 m |
| Notes: | DN 200<br>PN01<br>SN 10.000<br>Kut iskopa 90° |

| | |
|---|---|
| Kind of calculation: | Nominal stiffness |
| Add sketch to print: | Yes |

## 3.1 Input

### 3.1.1 Safety factors

| | |
|---|---|
| Safety class: | A (normal case) |
| Safety stability according to table 13: | Without predeformation (2.5 / 2.0) |
| Allowable deflection: | 6% (standard) |
| Treatment of internal pressure: | In accordance with Footnote 39 in ATV-DVWK-A 127 |
| Lower safety factors for flexural compression: | No (ATV-DVWK-A 127) |
| Proof for not predominantly static loading: | According to standard |
| Consideration of dyn pvh*: | According to standard |
| Consideration of Type A 'predeformation' in the deformation proof: | Yes |

### 3.1.2 Soil

| | | | |
|---|---|---|---|
| Soil group backfill: | G1 | | |
| Calculation E1: | Table 8 (A127) | | |
| Soil group pipe zone: | G1 | | |
| Calculation E20: | Table 8 (A127) | | |
| Soil group native soil: | G3 | | |
| Calculation E3: | Compression ratio | | |
| Compression ratio E3: | $D_{Pr,E3}$ | 90.0 | % |
| E4 = 10 · E1: | Yes | | |
| Application of silo theory: | Automatic | | |

### 3.1.3 Load

| | | | |
|---|---|---|---|
| Cover depth: | $h$ | 4.00 | m |
| Minimum groundwater level above pipe bed: | $h_{W,min}$ | 0.00 | m |
| Maximum groundwater level above pipe bed: | $h_{W,max}$ | 0.00 | m |
| Soil density: | $\gamma$ | 20.0 | kN/m³ |
| Additional surface load: | $p_0$ | 0.0 | kN/m² |
| Inner pressure, short term: | $P_{I,K}$ | 0.00 | bar |
| Inner pressure, long term: | $P_{I,L}$ | 0.00 | bar |
| Water fill (e.g. damming channel): | Yes | | |
| Density of medium: | $\gamma_F$ | 10.0 | kN/m³ |
| Input special-purpose vehicle: | No | | |
| Traffic load: | HGV 60 | | |
| Including horizontal loads due to traffic in the fatigue proof: | $\alpha_{qhT,dyn}$ | 0.00 | % |

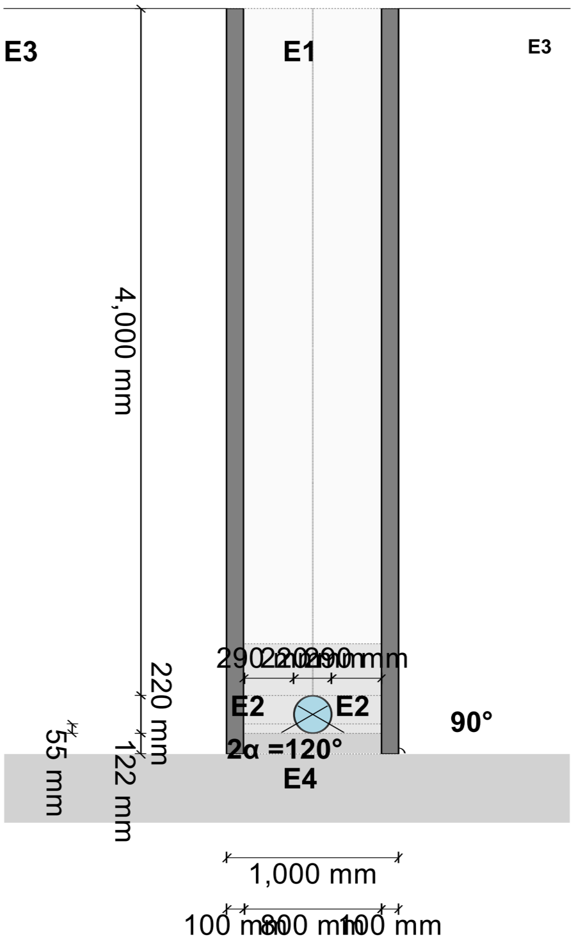
### 3.1.4 Installation

| | | | |
|---|---|---|---|
| Installation: | Trench | | |
| Trench width at pipe crown level: | b | 1.00 | m |
| Check minimum trench width: | Yes | | |
| Automatic consideration of bedding layer: | Yes | | |
| Slope angle: | ß | 90 | ° |
| Cover condition: | A2 | | |
| Installation condition: | B2 | | |
| Lining below pipe taken into account as per ATV Work Group 1.5.5 report.: | No | | |
| Thickness of bulkhead: | $b_S$ | 0.10 | m |
| Type of bedding: | Loose | | |
| Bedding angle: | 120° | | |
| Calculate bedding automatically: | Yes | | |
| Set lower height base: | No | | |
| Total height of base: | $h_s$ | 0.00 | m |

### 3.1.5 Pipe with nominal stiffness

| | | | |
|---|---|---|---|
| Pipe chosen from datebase: | No | | |
| Choice of input: | Do - s | | |
| Outer diameter: | $d_a$ | 220 | mm |
| Wall thickness: | t | 6.0 | mm |
| Local predeformation: | $\delta_{v,lokal}$ | 0.0 | % |
| Nominal stiffness: | SN | 10,000 | N/m² |
| Nominal pressure: | PN | 1.0 | bar |
| Relative failure strain according to standard: | Yes | | |
| Creep ratio: | $f_{Kriech}$ | 2.00 | [-] |
| Reduction factor due to temperature effect: | $A_{1,Temp}$ | 1.00 | [-] |
| Reduction factor due to media attack: | $A_{2,Medium}$ | 1.00 | [-] |
| Reduction factor due to dynamic loading: | $A_{3,dyn}$ | 1.00 | [-] |
| Specific gravity: | $\gamma_R$ | 18.00 | kN/m³ |
| Poissons ratio: | v | 0.30 | [-] |
| Input of ultimate hoop tensile stress: | No | | |
| Ultimate strain tensile strength according to standard: | Yes | | |
| Amplitude with 2·10^6 tests is known: | Yes | | |
| Amplitude with 2·10^6 tests: | $2\sigma_{a,2E6}$ | 39.00 | N/mm² |
| Amplitude with 1·10^8 tests is known: | Yes | | |
| Amplitude of the pipe with 1·10^8 tests: | $2\sigma_{a,1E8}$ | 24.00 | N/mm² |

**Traffic load: HGV 60**



## 3.2 Results

### 3.2.1 Minimum trench width according to DIN EN 1610:2015-12

**The minimum trench width at trench sole level falls short of DIN EN 1610.**

### 3.2.2 Section forces

| | | | |
|---|---|---|---|
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 14.75 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 7.374 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because SBh < 6 N/mm².

| | | | |
|---|---|---|---|
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 14.75 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 7.374 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because SBh < 6 N/mm².

### 3.2.3 Short term load case

3.2.3.1 Strain proof

| | | crown | springline | invert | |
|---|---|---|---|---|---|
| Safety coefficient outside | $\gamma$ | -11.759 | 25.915 | -9.113 | [-] |
| Safety coefficient Inside | $\gamma$ | 15.302 | -14.097 | 11.162 | [-] |

(Safety coefficients for flexural compressive stress are marked with a minus sign)

| | | | |
|---|---|---|---|
| Required safety coifficient, bending tensile stress: | erf $\gamma_{RBZ}$ | 2.00 | [-] |
| Required safety coifficient, bending compressive stress: | erf $\gamma_{RBD}$ | 2.00 | [-] |

All calculated safety coefficients of the strain proof are sufficient.

3.2.3.2 Deformation proof

| | | | |
|---|---|---|---|
| Total vertical deformation (Type A + Type B): | $\delta_{v,Ges}$ | 2.58 | % |
| Allowable deflection: | zul $\delta_v$ | 6.00 | % |

The deflection determined is less than the allowable deflection.

### 3.2.4 Long term load case

3.2.4.1 Strain proof

| | | crown | springline | invert | |
|---|---|---|---|---|---|
| Safety coefficient outside | $\gamma$ | -6.497 | 31.637 | -4.618 | [-] |
| Safety coefficient Inside | $\gamma$ | 10.141 | -9.126 | 6.235 | [-] |

(Safety coefficients for flexural compressive stress are marked with a minus sign)

| | | | |
|---|---|---|---|
| Required safety coifficient, bending tensile stress: | erf $\gamma_{RBZ}$ | 2.00 | [-] |
| Required safety coifficient, bending compressive stress: | erf $\gamma_{RBD}$ | 2.00 | [-] |

All calculated safety coefficients of the strain proof are sufficient.

3.2.4.2 Deformation proof

| | | | |
|---|---|---|---|
| Total vertical deformation (Type A + Type B): | $\delta_{v,Ges}$ | 2.71 | % |
| Allowable deflection: | zul $\delta_v$ | 6.00 | % |

The deflection determined is less than the allowable deflection.

3.2.4.3 Stabilty proof radial, linear

**Earth and traffic loads**

| | | | |
|---|---|---|---|
| Critical vertical total load: | krit $q_v$ | 708.0 | kN/m² |
| Total vertical load: | $q_v$ | 79.29 | kN/m² |
| Safety stability, radial: | $\gamma_{Stab,rad}$ | 8.93 | [-] |
| Required safety coifficient, instability (buckling): | erf $\gamma_{stab}$ | 2.50 | [-] |

The buckling proof is fulfilled.

3.2.4.4 stability proof, nonlinear

The nonlinear stability proof is not applicable because of VRB > 1.0 (rigid pipe) or relative vertical deformation < 6%.

3.2.4.5 Proof of safety against failure with not predominantly static loading

According to the standard the dynamic proof is not required (e.g. traffic load > 1,5 m).

All necessary proofs are ok.

# 4 Statics according to ATV-DVWK-A 127, 3rd edition: Cevovod 2, minimalni nadsloj 0.8 m

| | |
|---|---|
| Caption of this part of the calculation: | Cevovod 2, minimalni nadsloj 0.8 m |
| Notes: | DN 200<br>PN01<br>SN 10.000<br>Kut iskopa 70° |

| | |
|---|---|
| Kind of calculation: | Nominal stiffness |
| Add sketch to print: | Yes |

## 4.1 Input

### 4.1.1 Safety factors

| | |
|---|---|
| Safety class: | A (normal case) |
| Safety stability according to table 13: | Without predeformation (2.5 / 2.0) |
| Allowable deflection: | 6% (standard) |
| Treatment of internal pressure: | In accordance with Footnote 39 in ATV-DVWK-A 127 |
| Lower safety factors for flexural compression: | No (ATV-DVWK-A 127) |
| Proof for not predominantly static loading: | According to standard |
| Consideration of dyn pvh*: | According to standard |
| Consideration of Type A 'predeformation' in the deformation proof: | Yes |

### 4.1.2 Soil

| | | | |
|---|---|---|---|
| Soil group backfill: | G1 | | |
| Calculation E1: | Table 8 (A127) | | |
| Soil group pipe zone: | G1 | | |
| Calculation E20: | Table 8 (A127) | | |
| Soil group native soil: | G3 | | |
| Calculation E3: | Compression ratio | | |
| Compression ratio E3: | $D_{Pr,E3}$ | 90.0 | % |
| E4 = 10 · E1: | Yes | | |
| Application of silo theory: | Automatic | | |

### 4.1.3 Load

| | | | |
|---|---|---|---|
| Cover depth: | $h$ | 0.80 | m |
| Minimum groundwater level above pipe bed: | $h_{W,min}$ | 0.00 | m |
| Maximum groundwater level above pipe bed: | $h_{W,max}$ | 0.00 | m |
| Soil density: | $\gamma$ | 20.0 | kN/m³ |
| Additional surface load: | $p_0$ | 0.0 | kN/m² |
| Inner pressure, short term: | $P_{I,K}$ | 0.00 | bar |
| Inner pressure, long term: | $P_{I,L}$ | 0.00 | bar |
| Water fill (e.g. damming channel): | Yes | | |
| Density of medium: | $\gamma_F$ | 10.0 | kN/m³ |
| Input special-purpose vehicle: | No | | |
| Traffic load: | HGV 60 | | |
| Including horizontal loads due to traffic in the fatigue proof: | $\alpha_{qhT,dyn}$ | 0.00 | % |

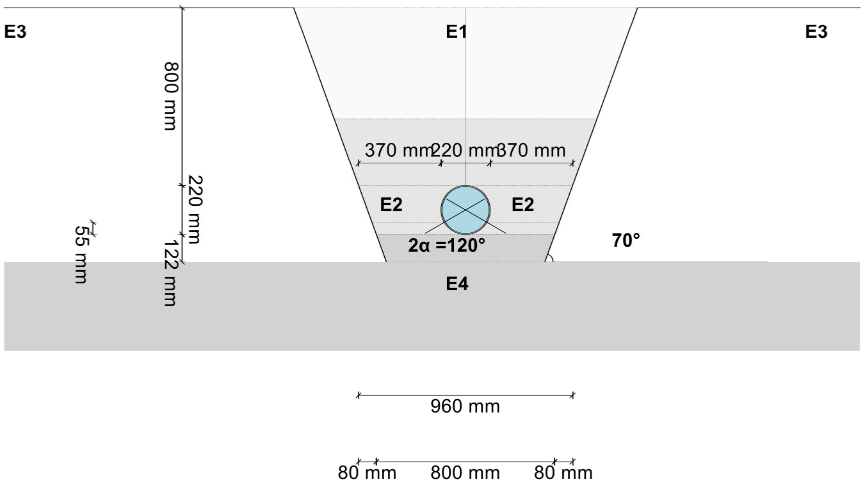
### 4.1.4 Installation

| | | | |
|---|---|---|---|
| Installation: | Trench | | |
| Trench width at pipe crown level: | b | 0.96 | m |
| Check minimum trench width: | Yes | | |
| Automatic consideration of bedding layer: | Yes | | |
| Slope angle: | ß | 70 | ° |
| Cover condition: | A1 | | |
| Installation condition: | B1 | | |
| Type of bedding: | Loose | | |
| Bedding angle: | 120° | | |
| Calculate bedding automatically: | Yes | | |
| Set lower height base: | No | | |
| Total height of base: | $h_s$ | 0.00 | m |

### 4.1.5 Pipe with nominal stiffness

| | | | |
|---|---|---|---|
| Pipe chosen from datebase: | No | | |
| Choice of input: | Do - s | | |
| Outer diameter: | $d_a$ | 220 | mm |
| Wall thickness: | t | 6.0 | mm |
| Local predeformation: | $\delta_{v,lokal}$ | 0.0 | % |
| Nominal stiffness: | SN | 10,000 | N/m² |
| Nominal pressure: | PN | 1.0 | bar |
| Relative failure strain according to standard: | Yes | | |
| Creep ratio: | $f_{Kriech}$ | 2.00 | [-] |
| Reduction factor due to temperature effect: | $A_{1,Temp}$ | 1.00 | [-] |
| Reduction factor due to media attack: | $A_{2,Medium}$ | 1.00 | [-] |
| Reduction factor due to dynamic loading: | $A_{3,dyn}$ | 1.00 | [-] |
| Specific gravity: | $\gamma_R$ | 18.00 | kN/m³ |
| Poissons ratio: | v | 0.30 | [-] |
| Input of ultimate hoop tensile stress: | No | | |
| Ultimate strain tensile strength according to standard: | Yes | | |
| Amplitude with 2·10^6 tests is known: | Yes | | |
| Amplitude with 2·10^6 tests: | $2\sigma_{a,2E6}$ | 39.00 | N/mm² |
| Amplitude with 1·10^8 tests is known: | Yes | | |
| Amplitude of the pipe with 1·10^8 tests: | $2\sigma_{a,1E8}$ | 24.00 | N/mm² |

**Traffic load: HGV 60**



## 4.2 Results

### 4.2.1 Minimum trench width according to DIN EN 1610:2015-12

The minimum trench width at trench sole level according DIN EN 1610 is met.

### 4.2.2 Section forces

| | | | |
|---|---|---|---|
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 75.02 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 37.512 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because of a compression ratio < 97% (chosen manually or due to ATV-DVWK-A 127 table 8; here for B4 ≥ 97% only).

| | | | |
|---|---|---|---|
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 75.02 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 37.512 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because of a compression ratio < 97% (chosen manually or due to ATV-DVWK-A 127 table 8; here for B4 ≥ 97% only).

### 4.2.3 Short term load case

4.2.3.1 Strain proof

| | | crown | springline | invert | |
|---|---|---|---|---|---|
| Safety coefficient outside | $\gamma$ | -12.138 | 75.668 | -9.236 | [-] |
| Safety coefficient Inside | $\gamma$ | 15.829 | -21.650 | 11.291 | [-] |

(Safety coefficients for flexural compressive stress are marked with a minus sign)

| | | | |
|---|---|---|---|
| Required safety coifficient, bending tensile stress: | erf $\gamma_{RBZ}$ | 2.00 | [-] |
| Required safety coifficient, bending compressive stress: | erf $\gamma_{RBD}$ | 2.00 | [-] |

All calculated safety coefficients of the strain proof are sufficient.

4.2.3.2 Deformation proof

| | | | |
|---|---|---|---|
| Total vertical deformation (Type A + Type B): | $\delta_{v,Ges}$ | 2.35 | % |
| Allowable deflection: | zul $\delta_v$ | 6.00 | % |

The deflection determined is less than the allowable deflection.

### 4.2.4 Long term load case

4.2.4.1 Strain proof

| | | crown | springline | invert | |
|---|---|---|---|---|---|
| Safety coefficient outside | $\gamma$ | -10.647 | 83.259 | -7.897 | [-] |
| Safety coefficient Inside | $\gamma$ | 14.097 | -19.757 | 9.657 | [-] |

(Safety coefficients for flexural compressive stress are marked with a minus sign)

| | | | |
|---|---|---|---|
| Required safety coifficient, bending tensile stress: | erf $\gamma_{RBZ}$ | 2.00 | [-] |
| Required safety coifficient, bending compressive stress: | erf $\gamma_{RBD}$ | 2.00 | [-] |

All calculated safety coefficients of the strain proof are sufficient.

4.2.4.2 Deformation proof

| | | | |
|---|---|---|---|
| Total vertical deformation (Type A + Type B): | $\delta_{v,Ges}$ | 2.38 | % |
| Allowable deflection: | zul $\delta_v$ | 6.00 | % |

The deflection determined is less than the allowable deflection.

4.2.4.3 Stabilty proof radial, linear

**Earth and traffic loads**

| | | | |
|---|---|---|---|
| Critical vertical total load: | krit $q_V$ | 1,373.1 | kN/m² |
| Total vertical load: | $q_V$ | 87.51 | kN/m² |
| Safety stability, radial: | $\gamma_{Stab,rad}$ | 15.69 | [-] |
| Required safety coifficient, instability (buckling): | erf $\gamma_{stab}$ | 2.50 | [-] |

The buckling proof is fulfilled.

4.2.4.4 stability proof, nonlinear

The nonlinear stability proof is not applicable because of VRB > 1.0 (rigid pipe) or relative vertical deformation < 6%.

4.2.4.5 Proof of safety against failure with not predominantly static loading

| | | | |
|---|---|---|---|
| Amplitude for 6·10^6 load cycles: | $2\sigma_{a,2E6}$ | 39.000 | N/mm² |
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 75.02 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 37.512 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because of a compression ratio < 97% (chosen manually or due to ATV-DVWK-A 127 table 8; here for B4 ≥ 97% only).

| | | | | | |
|---|---|---|---|---|---|
| Inside | | | | | |
| Dynamic stress portion external | dyn $\sigma_{pV}$ | 19.050 | -19.992 | 20.034 | N/mm² |
| Safety coefficient external: | dyn $\gamma$ | 2.047 | --- | 1.947 | [-] |
| Required safety coefficient: | | | erf $\gamma$ | 1.000 | [-] |
| outside | | | | | |
| Dynamic stress portion external | dyn $\sigma_{pV}$ | -18.315 | 17.945 | -19.335 | N/mm² |
| Safety coefficient external: | dyn $\gamma$ | --- | 2.173 | --- | [-] |
| Required safety coefficient: | | | erf $\gamma$ | 1.000 | [-] |

The determined safety coefficients are sufficient.

All necessary proofs are ok.

# 5 Statics according to ATV-DVWK-A 127, 3rd edition: Cevovod 2, maksimalni nadsloj 3 m

| | |
|---|---|
| Caption of this part of the calculation: | Cevovod 2, maksimalni nadsloj 3 m |
| Notes: | DN 200<br>PN01<br>SN 10.000<br>Kut iskopa 70° |

| | |
|---|---|
| Kind of calculation: | Nominal stiffness |
| Add sketch to print: | Yes |

## 5.1 Input

### 5.1.1 Safety factors

| | |
|---|---|
| Safety class: | A (normal case) |
| Safety stability according to table 13: | Without predeformation (2.5 / 2.0) |
| Allowable deflection: | 6% (standard) |
| Treatment of internal pressure: | In accordance with Footnote 39 in ATV-DVWK-A 127 |
| Lower safety factors for flexural compression: | No (ATV-DVWK-A 127) |
| Proof for not predominantly static loading: | According to standard |
| Consideration of dyn pvh*: | According to standard |
| Consideration of Type A 'predeformation' in the deformation proof: | Yes |

### 5.1.2 Soil

| | | | |
|---|---|---|---|
| Soil group backfill: | G1 | | |
| Calculation E1: | Table 8 (A127) | | |
| Soil group pipe zone: | G1 | | |
| Calculation E20: | Table 8 (A127) | | |
| Soil group native soil: | G3 | | |
| Calculation E3: | Compression ratio | | |
| Compression ratio E3: | $D_{Pr,E3}$ | 90.0 | % |
| E4 = 10 · E1: | Yes | | |
| Application of silo theory: | Automatic | | |

### 5.1.3 Load

| | | | |
|---|---|---|---|
| Cover depth: | h | 3.00 | m |
| Minimum groundwater level above pipe bed: | $h_{W,min}$ | 0.00 | m |
| Maximum groundwater level above pipe bed: | $h_{W,max}$ | 0.00 | m |
| Soil density: | γ | 20.0 | kN/m³ |
| Additional surface load: | $p_0$ | 0.0 | kN/m² |
| Inner pressure, short term: | $P_{I,K}$ | 0.00 | bar |
| Inner pressure, long term: | $P_{I,L}$ | 0.00 | bar |
| Water fill (e.g. damming channel): | Yes | | |
| Density of medium: | $\gamma_F$ | 10.0 | kN/m³ |
| Input special-purpose vehicle: | No | | |
| Traffic load: | HGV 60 | | |
| Including horizontal loads due to traffic in the fatigue proof: | $\alpha_{qhT,dyn}$ | 0.00 | % |

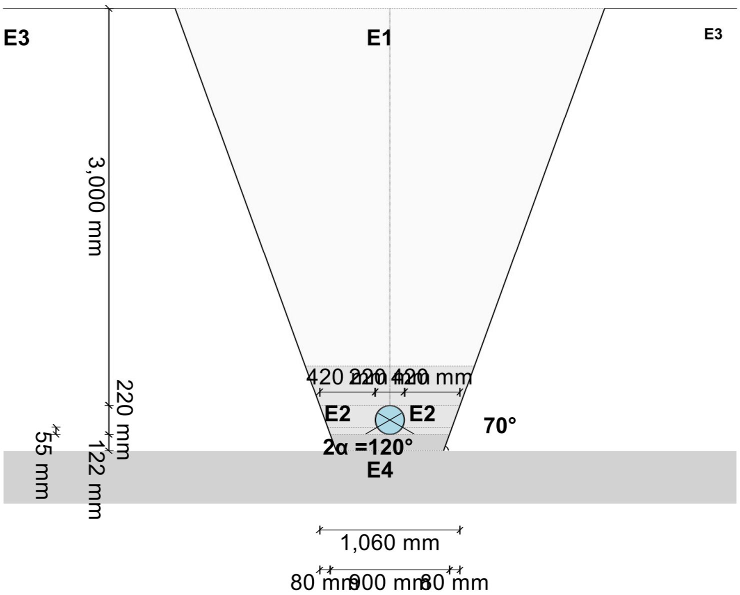
### 5.1.4 Installation

| | | | |
|---|---|---|---|
| Installation: | Trench | | |
| Trench width at pipe crown level: | b | 1.06 | m |
| Check minimum trench width: | Yes | | |
| Automatic consideration of bedding layer: | Yes | | |
| Slope angle: | ß | 70 | ° |
| Cover condition: | A1 | | |
| Installation condition: | B1 | | |
| Type of bedding: | Loose | | |
| Bedding angle: | 120° | | |
| Calculate bedding automatically: | Yes | | |
| Set lower height base: | No | | |
| Total height of base: | $h_s$ | 0.00 | m |

### 5.1.5 Pipe with nominal stiffness

| | | | |
|---|---|---|---|
| Pipe chosen from datebase: | No | | |
| Choice of input: | Do - s | | |
| Outer diameter: | $d_a$ | 220 | mm |
| Wall thickness: | t | 6.0 | mm |
| Local predeformation: | $\delta_{v,lokal}$ | 0.0 | % |
| Nominal stiffness: | SN | 10,000 | N/m² |
| Nominal pressure: | PN | 1.0 | bar |
| Relative failure strain according to standard: | Yes | | |
| Creep ratio: | $f_{Kriech}$ | 2.00 | [-] |
| Reduction factor due to temperature effect: | $A_{1,Temp}$ | 1.00 | [-] |
| Reduction factor due to media attack: | $A_{2,Medium}$ | 1.00 | [-] |
| Reduction factor due to dynamic loading: | $A_{3,dyn}$ | 1.00 | [-] |
| Specific gravity: | $\gamma_R$ | 18.00 | kN/m³ |
| Poissons ratio: | v | 0.30 | [-] |
| Input of ultimate hoop tensile stress: | No | | |
| Ultimate strain tensile strength according to standard: | Yes | | |
| Amplitude with 2·10^6 tests is known: | Yes | | |
| Amplitude with 2·10^6 tests: | $2\sigma_{a,2E6}$ | 39.00 | N/mm² |
| Amplitude with 1·10^8 tests is known: | Yes | | |
| Amplitude of the pipe with 1·10^8 tests: | $2\sigma_{a,1E8}$ | 24.00 | N/mm² |

**Traffic load: HGV 60**



## 5.2 Results

### 5.2.1 Minimum trench width according to DIN EN 1610:2015-12

The minimum trench width at trench sole level according DIN EN 1610 is met.

### 5.2.2 Section forces

| | | | |
|---|---|---|---|
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 20.84 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 10.421 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because of a compression ratio < 97% (chosen manually or due to ATV-DVWK-A 127 table 8; here for B4 ≥ 97% only).

| | | | |
|---|---|---|---|
| Included impact factor: | $\phi$ | 1.20 | [-] |
| Stresses due to traffic load (dynamic proof): | $p_T$ | 20.84 | kN/m² |
| Reduction factor αV according table 14 for traffic load: | $\alpha_V$ | 0.50 | [-] |
| Reduced vertical soil stress due to traffic load: | dyn $p_V$ | 10.421 | kN/m² |

The supporting effect of the bedding reaction pressure dyn pVh* is not applied because of a compression ratio < 97% (chosen manually or due to ATV-DVWK-A 127 table 8; here for B4 ≥ 97% only).

### 5.2.3 Short term load case

5.2.3.1 Strain proof

| | | crown | springline | invert | |
|---|---|---|---|---|---|
| Safety coefficient outside | $\gamma$ | -23.193 | 8,601.102 | -15.782 | [-] |
| Safety coefficient Inside | $\gamma$ | 40.515 | -39.902 | 22.406 | [-] |

(Safety coefficients for flexural compressive stress are marked with a minus sign)

| | | | |
|---|---|---|---|
| Required safety coifficient, bending tensile stress: | erf $\gamma_{RBZ}$ | 2.00 | [-] |
| Required safety coifficient, bending compressive stress: | erf $\gamma_{RBD}$ | 2.00 | [-] |

All calculated safety coefficients of the strain proof are sufficient.

5.2.3.2 Deformation proof

| | | | |
|---|---|---|---|
| Total vertical deformation (Type A + Type B): | $\delta_{v,Ges}$ | 1.66 | % |
| Allowable deflection: | zul $\delta_v$ | 6.00 | % |

The deflection determined is less than the allowable deflection.

### 5.2.4 Long term load case

5.2.4.1 Strain proof

| | | crown | springline | invert | |
|---|---|---|---|---|---|
| Safety coefficient outside | $\gamma$ | -13.064 | -51.607 | -8.174 | [-] |
| Safety coefficient Inside | $\gamma$ | 29.191 | -28.557 | 12.540 | [-] |

(Safety coefficients for flexural compressive stress are marked with a minus sign)

| | | | |
|---|---|---|---|
| Required safety coifficient, bending tensile stress: | erf $\gamma_{RBZ}$ | 2.00 | [-] |
| Required safety coifficient, bending compressive stress: | erf $\gamma_{RBD}$ | 2.00 | [-] |

All calculated safety coefficients of the strain proof are sufficient.

5.2.4.2 Deformation proof

| | | | |
|---|---|---|---|
| Total vertical deformation (Type A + Type B): | $\delta_{v,Ges}$ | 1.72 | % |
| Allowable deflection: | zul $\delta_v$ | 6.00 | % |

The deflection determined is less than the allowable deflection.

5.2.4.3 Stabilty proof radial, linear

**Earth and traffic loads**

| | | | |
|---|---|---|---|
| Critical vertical total load: | krit $q_v$ | 1,194.4 | kN/m² |
| Total vertical load: | $q_v$ | 64.99 | kN/m² |
| Safety stability, radial: | $\gamma_{Stab,rad}$ | 18.38 | [-] |
| Required safety coifficient, instability (buckling): | erf $\gamma_{stab}$ | 2.50 | [-] |

The buckling proof is fulfilled.

5.2.4.4 stability proof, nonlinear

The nonlinear stability proof is not applicable because of VRB > 1.0 (rigid pipe) or relative vertical deformation < 6%.

5.2.4.5 Proof of safety against failure with not predominantly static loading

According to the standard the dynamic proof is not required (e.g. traffic load > 1,5 m).

All necessary proofs are ok.