National technical approval / General construction technique permit

Number: Z-42.3-490

Applicant:
Brandenburger Liner GmbH & Co. KG
Taubensuhlstraße 6
76829 Landau/Pfalz, Germany

Validity
from: 24 January 2019
to: 14 September 2022

Subject of decision:
"Brandenburger Liner BB 1.0, BB 2.0 and BB 2.5" pipe liner for the rehabilitation of underground damaged sewers with cross-sections in the form of circular profiles from DN 150 to DN 1600 and oval profiles from 200 mm/300 mm to 1200 mm/1800 mm

The subject named above is herewith granted a national technical approval (allgemeine bauaufsichtliche Zulassung)/general construction technique permit (allgemeine Bauartgenehmigung). This decision contains 23 pages and 34 annexes. This national technical approval/general construction technique permit replaces national technical approval no. Z-42.3-490 of 14 September 2017.

Translation authorised by DIBt
I GENERAL PROVISIONS

1 This decision confirms the fitness for use and application of the subject concerned in accordance with the Building Codes of the federal states (Landesbauordnungen).

2 This decision does not replace the permits, approvals and certificates required by law for carrying out building projects.

3 This decision is granted without prejudice to the rights of third parties, in particular private property rights.

4 Notwithstanding further provisions in the 'Special Provisions', copies of this decision shall be made available to the user and installer of the subject concerned. The user and installer of the subject concerned shall also be made aware that this decision must be made available at the place of use or place of application. Upon request, copies of the decision shall be provided to the authorities involved.

5 This decision shall be reproduced in full only. Partial publication requires the consent of Deutsches Institut für Bautechnik. Texts and drawings in promotional material shall not contradict this decision. In the event of a discrepancy between the German original and this authorised translation, the German version shall prevail.

6 This decision may be revoked. The provisions may subsequently be supplemented and amended, in particular if this is required by new technical findings.

7 This decision is based on the information and documents provided by the applicant. Alterations to this basis are not covered by this decision and shall be notified to DIBt without delay.

8 The general construction technique permit included in this decision also serves as a national technical approval for the construction technique.
II  SPECIAL PROVISIONS

1  Subject of approval and field of application

This national technical approval applies to the production and use of the pipe liners "Brandenburger Liner BB 1.0", "Brandenburger Liner BB 2.0" and "Brandenburger Liner BB 2.5" (Annex 1) using polyester or vinyl ester resins and glass-fibre reinforced plastic tubes (GRP tube) to renovate or rehabilitate damaged sewers with circular profiles in the nominal diameter range DN 150 to DN 300 using the "Brandenburger Liner BB 1.0" and DN 150 to DN 1600 as well as oval profiles with width and height dimensions of 200 mm/300 mm to 1200 mm/1800 mm at a ratio of approx. W:H = 2:3 using the "Brandenburger Liner BB 2.0" and "Brandenburger Liner BB 2.5".

This approval applies to the renovation or rehabilitation of sewers designed for wastewater in accordance with DIN 1986-3\(^1\).

The pipe liners can be used to renovate or rehabilitate sewers made of concrete, reinforced concrete, vitrified clay, asbestos-free fibre cement, GRP, PVC-U, PE-HD and cast iron provided that the cross-section of the sewer to be rehabilitated satisfies the method-related requirements and the structural requirements.

Damaged sewers are rehabilitated by inserting a resin-impregnated seamless glass fibre tube or glass/polyester fleece mats and curing it/them with UV radiation.

Watertight renewal of the lateral inlets (residential connections) out of the respective rehabilitated sewer is only permissible using methods for which a national technical approval (allgemeine bauaufsichtliche Zulassung) applies.

Residential connections may also be restored either using an open construction or by means of a renovation or rehabilitation method for which national technical approvals (allgemeine bauaufsichtliche Zulassungen) apply.

2  Provisions for the construction products

2.1  Properties and composition

Where applicable, the pipe liners set out in Section 1 fulfil the requirements contained in DIN EN ISO 11296-4\(^2\). They have the specific properties and compositions listed below.

2.1.1  Materials of the pipe liner components – "M" stage

2.1.1.1  Tube materials

The material for the PE preliner (Variation 1, Annex 2) or the additional fibre-reinforced external protective PVC foil (Variation 2, Annex 3), the 'pull strap' and the outer fleece-laminated PE/PA/PE multi-layer compound foil and the inner PE/PA protective foil shall conform to the formulations deposited with Deutsches Institut für Bautechnik.

For impregnating the glass-fibre tubes or the glass/polyester fleece mats, only resins and curing components may be used which also conform to the formulations deposited with Deutsches Institut für Bautechnik.

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\(^1\) DIN 1986-3

Drainage systems on private ground – Part 3: Specifications for service and maintenance; issue: 2004-11

\(^2\) DIN EN ISO 11296-4

Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks – Part 4: Lining with cured-in-place pipes (ISO 11296-4:2018); German version EN ISO 11296-4:2018; issue: 2018-09
No. Z-42.3-490  

Only unsaturated polyester resins (UP resins in accordance with DIN 18820-1, Table 1 group 3 and in accordance with DIN EN 13121-1, Table 2 group 4 and Iso-Npg and Ortho-Npg) of type 1140 in accordance with DIN 16946-2, Table 3, as well as vinyl ester resins (VE resins in accordance with DIN 18820-1, Table 1 group 5 and in accordance with DIN EN 13121-1, Table 2 group 7A) of type 1310 in accordance with DIN 16946-2, Table 4, shall be used.

The polyester and vinyl resins conform to the IR spectra deposited with Deutsches Institut für Bautechnik. The IR spectra shall also be deposited with the external surveillance body.

Only E-CR glass fibres in the form of multi-layered glass fibre sheets (tangled fibre layers and layer-directed fibres) may be used which correspond to the specifications of DIN EN 14020-1, DIN EN 14020-2 and DIN EN 14020-3.

The glass/polyester fleece mats shall have the following properties:
- Tensile strength lengthwise and crosswise based on DIN EN ISO 29073-3: 250 N/5 cm
- Elongation lengthwise based on DIN EN ISO 29073-3: 30%
- Elongation crosswise based on DIN EN ISO 29073-3: 40%
- Thickness based on DIN EN ISO 9073-2: 1.0 mm to 1.4 mm

2.1.1.2 Materials used for the swelling tape (auxiliary material)

Only extruded profiles consisting of chloroprene rubber (CR/SBR) and water-absorbing resin shall be used for the swelling tape (auxiliary material, see Annex 32) in areas where the pipe liner is connected to a manhole. The swelling tape shall have a volume increase of at least 100% after 72 h of immersion in water.

2.1.2 Environmental safety

The construction product meets the requirements of the principles given in ‘Assessment of the impact of building products on soil and groundwater’ (Bewertung der Auswirkungen von Bauprodukten auf Boden und Grundwasser) (version: 2011; publications of Deutsches Institut für Bautechnik). This statement only applies if the special provisions in this national technical approval (allgemeine bauprüftechnische Zulassung) are complied with.

The reservation of authorisation, particularly in water protection areas, by the competent water authority remains unaffected.

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Translation authorised by DIBt
2.2 Manufacture, packaging, transport, storage and marking

2.2.1 Standard factory production of GRP pipe liners

The glass fibre sheets and glass/polyester fleece mats with properties in accordance with Section 2.1.1.1, purchased from suppliers as rolled goods, shall be unwound in an impregnation plant and drawn through a bath with resin in accordance with Section 2.1.1.1. After impregnation, the sheets shall be rolled up and packed in a light-proof manner.

During resin impregnation, the following parameters shall be monitored:
- Evenness and cleanliness of the substrate
- Evenness of the resin impregnation

During resin impregnation, the following parameters shall be monitored and recorded:
- Resin content

The resin-impregnated rolls can be stored in their light-proof packaging in intermediate storage for approx. 26 weeks.

For the manufacture of the nominal diameter related GRP pipe liner, the resin-impregnated rolls shall be inserted into the wrapping machine. The wrapping machine shall also be loaded with the fleece-laminated PE/PA/PE multi-layer compound foils. In automated manufacturing, the resin-impregnated glass fibre sheets or glass/polyester fleece mats shall be removed from the individual rolls and wrapped continuously around a mandrel which is covered in PE/PA protection foil. In the area of the apex and the base, so called "pull straps" shall be applied. Afterwards, the tube created in this manner shall be welded or glued into the outer fleece-laminated PE/PA/PE multi-layer compound foil.

During the manufacturing of the tube, the following parameters shall be monitored:
- Evenness of resin impregnation of every single sheets
- Monitoring of the welding parameters (e.g. welding temperature and evenness of welding connections of the fleece-laminated PE/PA/PE multi-layered compound foil)

During the manufacturing of the tube, the following parameters shall be monitored and recorded:
- Angles of the individual sheets from wrapping rate and feed rate
- Wall thickness
- Width (outer diameter of the horizontal and wrapped tubes)
- Tube length
- Machine setting
- Batch number of the impregnated glass fibre roll or glass/polyester fleece mats

The wrapped glass fibre liners or glass/polyester fleece mats shall be placed into light-proof transportation boxes immediately after the welding or gluing process.

The relevant accident prevention as well as health and safety at work provisions shall be complied with for factory resin impregnation of the glass fibre sheets or glass/polyester fleece mats and the manufacturing of the glass fibre tubes or glass/polyester fleece mats.

In particular, the specifications of the technical rule on hazardous substances TRGS 90011 "Threshold values in the air" (TRGS 900 Grenzwerte der Luft) in relation to styrene shall be complied with. Appropriate measures (e.g. use of exhaust systems) shall be taken to ensure the applicable styrene limit values are not exceeded.

The relevant accident prevention provisions and the regulations in accordance with the Ordinance on Hazardous Substances (Gefahrstoff-VO) shall be complied with during handling of the impregnated liners.

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2.2.2 Packaging, transport and storage

The resin delivered to the applicant's manufacturing plant for the factory production of tubes can be stored in suitable storage tanks, in temperature-controlled storage rooms with a monitored temperature range of +5 °C to approx. +30 °C.

The resin-impregnated glass fibre rolls or glass/polyester fleece mats in light-proof packaging can be stored in the intermediate storage of the manufacturer at temperatures from approx. +5 °C to +30 °C for a duration of approx. 26 weeks.

In the light-proof transportation boxes, the manufactured GRP pipe liners can be stored at a temperature from +5 °C to +30 °C for a duration of approx. 26 weeks. The transportation containers shall be protected from direct sunlight and heat sources.

The relevant accident prevention provisions shall be complied with during storage and transport.

2.2.3 Marking

The transportation boxes of the GRP pipe liners shall be marked with the national conformity mark (Ü-Zeichen) including the approval number Z-42.3-490, in accordance with the Conformity Marking Ordinances (Übereinstimmungszeichen-Verordnungen) of the federal states. The mark shall only be applied if the requirements given in Section 2.3 are met.

The manufacturer shall apply the hazard symbols and H and P statements to the containers, the packaging, the packing slip or the delivery note in accordance with the Hazardous Substances Ordinance (Gefahrstoffverordnung) and EU Directive No. 1907/2006 (REACH) as well as the latest version of the CLP Regulation (EC) 1272/200812. The packaging shall be marked in accordance with the rules of the ADR13 in the applicable versions.

In addition, the following information shall be given:
- Nominal size
- Wall thickness
- Tube length
- Pipe liner designation "Brandenburger Liner BB 1.0", "Brandenburger Liner BB 2.0" or "Brandenburger Liner BB 2.5"
- Resin type (UP or VE resin)
- Date of resin impregnation
- Production site (place where resin was impregnated)
- Identification number
- Storage temperature range
- Reference to light sensitivity

2.3 Confirmation of conformity

2.3.1 General

The confirmation of conformity of the pipe liners (construction products) with the provisions of the national technical approval included in this decision shall be issued for every manufacturing plant in the form of a declaration of conformity based on factory production control and a certificate of conformity issued by a certification body recognised for these purposes as well as on regular external surveillance carried out by a recognised inspection body, including initial type-testing of the construction products, in accordance with the following provisions.

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12 Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures
13 European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) (Accord européen relatif au transport international des marchandises Dangereuses par Route)
To issue the certificate of conformity and for external surveillance, including the associated product testing to be carried out in the process, the manufacturer of the construction products shall use an appropriately recognised certification body and an appropriately recognised inspection body.

The declaration of conformity shall be submitted by the manufacturer through marking of the construction products with the national conformity mark including statement of the intended use.

The certification body shall send a copy of the certificate of conformity issued by it to Deutsches Institut für Bautechnik.

A copy of the initial type testing evaluation report shall also be sent to Deutsches Institut für Bautechnik.

2.3.2 Factory production control
A factory production control system shall be set up and implemented in each manufacturing plant. Factory production control shall be understood to be continuous surveillance of production by the manufacturer to ensure that the manufactured construction products satisfy the provisions of the national technical approval included in this decision.

The factory production control shall at least include the measures listed below:

- **Description and verification of the starting material**
  
  a) Tube materials
  
  The operator of the manufacturing plant shall ensure that for each delivery of components, such as glass fibre tube, glass/polyester fleece mat, resin and curing agents, the properties required in accordance with Section 2.1.1 are complied with.
  
  For this purpose, the operator of the manufacturing plant shall obtain the corresponding declarations of compliance with the order "type 2.1" based on DIN EN 10204\(^\text{14}\) from the respective upstream supplier. Within the scope of the incoming inspection the following properties shall be verified:
  
  Resin properties:
  
  - Viscosity (visually)
  - Reactivity
  
  The reactivity shall be recorded for every resin batch.

  b) Materials used for the swelling tape (auxiliary material)
  
  For every delivery of swelling tapes, the applicant shall obtain confirmation that the specifications pertaining to the required properties given in Section 2.1.1.2 are complied with through submission of declarations of compliance 2.1 in accordance with DIN EN 10204\(^\text{14}\) by the upstream supplier.
  
  In the course of the incoming inspections, visual checks and measuring of random samples shall ensure that geometrical requirements of the swelling tapes (profile form and dimensions) in accordance with Annex 32 are complied with.

- Checks and tests to be carried out during manufacture:
  
  The requirements of Section 2.2.1 shall be checked.

The results of factory production control shall be recorded and evaluated. The records shall include at least the following information:

- designation of the construction products or the starting materials and the components
- type of check or test,
2.3.3 External surveillance

The factory production control system at each manufacturing plant shall be inspected regularly, i.e. at least once per half year, by means of external surveillance.

Initial type-testing of the construction products shall be carried out within the framework of external surveillance. Factory production control shall be carried out within the scope of external surveillance by means of spot checks. The requirements of Sections 2.1.1 and 2.2.3 shall be checked in the process.

Spot checks for compliance with the production requirements in accordance with Section 2.2.1 shall be carried out. These checks shall also include checks of the cure behaviour, storage stability, wall thicknesses and weight unit area after curing as well as the IR spectra.

Sampling and testing shall be the responsibility of the recognised inspection body. During the external surveillance, the declarations of compliance with the order "type 2.1" in accordance with DIN EN 10204\textsuperscript{14} shall also be checked.

The results of certification and external surveillance shall be kept for at least five years. They shall be presented by the certification or inspection body to Deutsches Institut für Bautechnik and the competent supreme building authority upon request.

3 Provisions for application of the subject of approval

3.1 Planning and design

3.1.1 Planning

A check shall be made to determine whether the required sewer and pipe data (e.g. pipe routing, depth, location of the residential connections, manhole depths, groundwater, pipe joints, hydraulic conditions, inspection chambers and cleaning intervals) are given. Existing video recordings shall be evaluated in a use-oriented way (Annex 20). The accuracy of the information provided shall be checked on-site. The condition of the existing sewer for drainage from the property shall be assessed for determining the applicability of the rehabilitation process.

The hydraulic performance of the sewers may not be impaired through introduction of a CIPP liner. The corresponding verification shall be provided, if necessary.
3.1.2 Design

3.1.2.1 Pipe liner – "I" stage

3.1.2.1.1 Wall thickness and structure

After it has been pulled in and cured, the GRP pipe liner shall have a multi-layered wall structure (Annex 1) consisting of the outer fleece-laminated PE/PA/PE multi-layer compound foil, the "pull strap" in the apex and base areas with a wall thickness of 0.5 mm, the GRP layer and the inner PE/PA protective foil, which is removed from the pipe liner after it has cured.

For Variation 1 (Annex 2) a PE preliner shall be used. For Variation 2 (Annex 3), a fibre-reinforced external protection foil made from PVC shall be used. Where applicable, a PE preliner can be additionally incorporated in Variation 2.

The wall thickness of the respective cured GRP pipe liner shall be checked by means of a structural analysis in accordance with work sheet DWA-A 143-2\(^{15}\) (please also see Section 3.1.2.1.4).

For the structural analysis, the ring stiffnesses of the cured GRP pipe liner and the corresponding wall thicknesses (wall thicknesses depending on the ring stiffness SR) shall be observed.

Within the scope of factory production control, spot checks of the statically required minimum wall thicknesses shall be performed on sample pieces of the GRP pipe liner by applying a pressure of 0.4 bar. The sample pieces shall be kept for at least two years as reference samples.

GRP pipe liners may be used for the rehabilitation of sewers with circular profiles and oval profiles if the ground system of the host pipe-soil system is load bearing on its own (without the support of the surrounding soil). If there are one or more continuous longitudinal cracks in the host pipe, soil investigations, e.g. by way of penetration tests, are required and appropriate design verification calculations shall be performed. In the event of infiltrations, the GRP pipe liner shall be assessed with regard to the deformation and buckling properties.

If the host pipe soil system alone is no longer sufficiently load-bearing, such sewers may only be rehabilitated using pipe liners if the static loads to be borne by the liner are verified through a structural analysis performed in accordance with work sheet DWA-A 143-2\(^{15}\).

The wall thickness may not be less than the minimum wall thickness of 3.0 mm in the cured state.

Pipe liners with a nominal stiffness from SN ≥ 500 N/m\(^2\) to SN ≥ 630 N/m\(^2\) with the respective wall thicknesses are also permissible.

For the nominal stiffness SN and short-term ring stiffness SR (Annexes 5 to 9), the following relations apply:

For SN:

\[
SN = \frac{E \cdot s^3}{12 \cdot d_m^3}
\]

For SR:

\[
SR = \frac{E \cdot s^3}{12 \cdot r_m^3}
\]

(SN = nominal stiffness based on DIN 16869-2\(^{16}\))

The wall stiffnesses given in Annex 4 shall be considered.
For the groundwater load case, the pipe liner shall be sized to accommodate bulges in accordance with work sheet DWA-A 143-2\textsuperscript{16} (please also see Section 3.1.2.1.4).

### 3.1.2.1.2Dimensions of pipe liners for oval profiles

Essentially, the pipe lining method may also be used to rehabilitate damaged sewers with oval shaped cross-sections, which correspond to the width and height dimensions given in Annex 4 with the respective wall thicknesses. Sewers with other width and height ratios may also be rehabilitated, based on assessments of the inner circumference of the sewer to be rehabilitated, which need to be performed on site.

### 3.1.2.1.3Physical characteristics of the cured glass fibre resin composite

The cured GRP pipe liners shall have the following properties (without PE/PA or PE/PE/PE coatings):

1. "Brandenburger Liner BB 1.0" DN 150 to DN 300 with glass/polyester fleece mats and with UP resin
   - Density based on DIN EN ISO 1183-2\textsuperscript{17}: 1.39 g/cm\(^3\) ± 0.2 g/cm\(^3\)
   - Glass/fibre surface weight of the glass/polyester fleece mats based on DIN EN ISO 29073-1\textsuperscript{18}: 670 g/m\(^2\) ± 10%
   - Glass fibre content based on DIN EN ISO 1172\textsuperscript{19}: mean value 40 % ± 5 % (weight-related) of glass/polyester fleece mats
   - Short-term circumferential modulus of elasticity with pull strap based on DIN EN 1228\textsuperscript{20}: 4,350 N/mm\(^2\)
   - Short-term flexural modulus without pull strap based on DIN EN ISO 11296-4\textsuperscript{21} or DIN EN ISO 178\textsuperscript{22}: 4,350 N/mm\(^2\) (radially)
   - Short-term flexural modulus with pull strap based on DIN EN ISO 11296-4\textsuperscript{21} or DIN EN ISO 178\textsuperscript{22} (radially):
   - Bending stress \(\sigma_\text{b}\) with and without pull strap based on DIN EN ISO 11296-4\textsuperscript{21} or DIN EN ISO 178\textsuperscript{22}: 105 N/mm\(^2\)

2. "Brandenburger Liner BB 2.0" DN 150 to DN 1600 with glass fibre tubes and with UP resin
   - Density based on DIN EN ISO 1183-2\textsuperscript{17}: 1.45 g/cm\(^3\) ± 0.2 g/cm\(^3\)
   - Glass surface weight:
   - Glass fibre content based on DIN EN ISO 1172\textsuperscript{19}: mean value 46% ± 5%
   - Short-term circumference modulus of elasticity based on DIN EN 1228\textsuperscript{20}:
   - Short-term modulus of elasticity in bending based on DIN EN ISO 11296-4\textsuperscript{21} or DIN EN ISO 178\textsuperscript{22} in the area of the springer: 8,400 N/mm\(^2\) (radially)

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\textsuperscript{18} DIN EN 29073-1 : Textiles; test method for nonwovens;-- Part 1: Determination of mass per unit area (ISO 9073-1:1989); German version EN 29073-1:1992, issue: 1992-08

\textsuperscript{19} DIN EN ISO 1172 : Textile-glass-reinforced plastics - Prepregs, moulding compounds and laminates - Determination of the textile-glass and mineral-filler content; calcination methods (ISO 1172:1996); German version EN ISO 1172:1998; issue: 1996-12

\textsuperscript{20} DIN EN 1228 : Plastics piping systems – Glass-reinforced thermosetting plastics (GRP) pipes – Determination of initial specific ring stiffness; German version EN 1228:1996; issue: 1996-08

National technical approval  
(algemeine bauaufsichtliche Zulassung)  
General construction technique permit (allgemeine Bauartgenehmigung)  

No. Z-42.3-490  

1. Short-term modulus of elasticity in bending  
   based on DIN EN ISO 11296-4² or DIN EN ISO 178²¹  
   in the area of the base and apex: 9,000 N/mm² (radially)  
   - Bending strength σ_B based on DIN EN ISO 11296-4² or  
     DIN EN ISO 178²¹ in the areas of the springer, base and apex: 150 N/mm²  

2. "Brandenburger Liner BB 2.5" DN 150 to DN 875 with glass fibre tubes and with UP and VE resin  
   - Density based on DIN EN ISO 1183-2¹⁷: 1.54 g/cm³ ± 0.2 g/cm³  
   - Glass surface weight: 730 g/m² ± 10 %  
   - Glass fibre content based on DIN EN ISO 1172¹⁹: mean value 49% ± 5%  
   - Short-term circumference modulus of elasticity  
     based on DIN EN 1228²⁰: 14,200 N/mm²  
   - Short-term modulus of elasticity in bending based  
     on DIN EN ISO 11296-4² or DIN EN ISO 178²¹  
     in the areas of the springer, base and apex: 11,800 N/mm² (radially)  
   - Bending strength σ_B based on DIN EN ISO 11296-4² or  
     DIN EN ISO 178²¹ in the areas of the springer, base and apex: 200 N/mm²  

4. "Brandenburger Liner BB 2.5" from >DN 875 to DN 1600 with glass fibre tubes and with UP and VE resin  
   - Density based on DIN EN ISO 1183-2¹⁷: 1.54 g/cm³ ± 0.2 g/cm³  
   - Glass surface weight: 730 g/m² ± 10 %  
   - Glass fibre content based on DIN EN ISO 1172¹⁹: mean value 49% ± 5%  
   - Short-term circumference modulus of elasticity  
     based on DIN EN 1228²⁰: 16,875 N/mm²  
   - Short-term modulus of elasticity in bending based  
     on DIN EN ISO 11296-4² or DIN EN ISO 178²¹  
     in the areas of the springer, base and apex: 13,600 N/mm² (radially)  
   - Bending strength σ_B based on DIN EN ISO 11296-4² or  
     DIN EN ISO 178²¹ in the areas of the springer, base and apex: 200 N/mm²  

3.1.2.1.4 Structural analysis of the cured pipe liner  
A structural analysis is to be performed to verify the stability of the planned pipe liner  
for each rehabilitation project in accordance with work sheet DWA-A 143-2¹⁵ of the German  
Association for Water, Wastewater and Waste (Deutsche Vereinigung für Wasserwirtschaft,  
Abwasser und Abfall e.V., DWA) before the work begins.  

In the structural analysis, a partial safety factor of γ_m = 1.35 shall be applied for the pipe liner  
material.  

The reduction factor A for determining the long-term values was determined based on  
DIN EN 761²² and shall be used in the structural analysis.  
This results in the following values for the modulus of elasticity and the bending strength in  
accordance with work sheet DWA-A 143-2¹⁵:  
1. "Brandenburger Liner BB 1.0" DN 150 to DN 300 with glass/polyester fleece mats and  
   with UP resin  
   - Short-term bending strength σ_B with pull strap based on  
     DIN EN ISO 11296-4² or DIN EN ISO 178²¹: 105 N/mm²  
   - Long-term bending strength σ_B²: 53 N/mm²  

DIN EN 761  
Plastics piping systems – Glass-reinforced thermosetting plastics (GRP) pipes –  
Determination of the creep factor under dry conditions; German version  
EN 761:1994; issue: 1994-08  

Translation authorised by DIBt
3.2 Execution

3.2.1 General

Damaged sewers are rehabilitated by inserting a resin-impregnated seamless glass fibre tube or glass/polyester fleece mats and curing it/them with UV radiation. For this, a "preliner", which is a protective foil made from PE (variation 1) or a protective tube made from fabric-reinforced PVC (variation 2), is inserted into the damaged sewer. For variation 2, an additional PE preliner can be inserted, if applicable. The resin-impregnated glass fibre tube or glass/polyester fleece mats with protective foils made from polyethylene/polyamide on both sides is/are pulled into the PE preliner or the fabric-reinforced protective PVC tube and inflated by applying compressed air.

A start and end pit (entry and exit manhole) are required for implementation of the "Brandenburger" pipe lining method. It is also possible to cross several manholes between the respective start and end points, including crossing through manholes with channel deflections of up to 15 degrees.

It is possible to rehabilitate a change of direction of 90° from nominal size DN 500. Special installation equipment of the applicant shall be used for this purpose.
If folding occurs, this may not be larger than specified in DIN EN ISO 11296-4\textsuperscript{2}. Residential connections are restored from the main pipe by means of robot technology using push-in bladders (inflatable seals). Residential connections shall be made either using an open construction or by means of a renovation or rehabilitation method (e.g. grouting technique) for which the national technical approvals apply.

The applicant shall supply the executing party with a manual containing a description of the individual steps for execution (see also Section 3.2.3 and Annexes 20 to 29).

The applicant shall also ensure that the executing parties have been sufficiently familiarised with the process. Verification that the executing company possesses sufficient technical knowledge can be provided through the corresponding quality mark from Güteschutz Kanalbau e.\textsuperscript{V}.\textsuperscript{23}

### 3.2.2 Equipment and facilities

Minimum equipment, component and facility requirements for execution of the rehabilitation process:

- Sewer cleaning equipment
- Sewer inspection equipment (DWA-M 149-2\textsuperscript{24})
- Vehicle equipment:
  - Pipe liner "Brandenburger Liner BB 1.0" or "Brandenburger Liner BB 2.0" (UP resin) or "Brandenburger Liner BB 2.5" (UP or VE resin) in accordance with Annex 2, Variation 1 or Annex 3, Variation 2
  - PE preliner (Variation 1, Annex 2), if applicable
  - UV light chains/UV light cores (based on nominal diameter) (Annexes 10 to 17)
  - Electrical wiring for transmission of temperature measurement data
  - Temperature measuring probes
  - Spare UV lamps
  - Intensity meter for UV radiation measurements
  - Swivels (to prevent twisting while the pipe liner is pulled in)
  - Sealing plugs depending on nominal size (referred to as packing, Annex 18 and 19) DN 150 to DN 1600 with compressed air connections
  - Compressor
  - Compressed air hoses
  - Centrifugal compressor
  - Cable winch with checking device for pulling forces
  - Workshop and equipment room
  - Electricity generator
  - Lifting device

\textsuperscript{23} Güteschutz Kanalbau e.\textsuperscript{V.}; Linzer Str. 21, Bad Honnef, Germany, Telephone: +49 (0) 2224 9384-0, Fax: +49 (0) 2224 9384-84

\textsuperscript{24} DWA-M 149-2

German Association for Water, Wastewater and Waste (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.\textsuperscript{V.}, DWA) – Advisory Leaflet 149: Conditions and Assessment of Drain and Sewer Systems Outside Buildings – Part 2: Visual inspection coding system; issue: 2013-12
Control unit with screen and video camera including computer-operated recording of curing parameters
Edge protection on the edges of the start or insertion manhole
Staff rooms and sanitation facilities (where required)

If electrical devices, e.g. video cameras (or remote-controlled pipe crawlers) need to be inserted into the pipe to be rehabilitated, they shall be designed in accordance with the VDE rules.

3.2.3 Rehabilitation project implementation

3.2.3.1 Preparatory measures

Before starting the work, the sewer to be rehabilitated shall be cleaned thoroughly (Annexes 20 and 22) so that the damage can be readily seen on the monitor. Any obstacles preventing the pulling in of the liner (e.g. ingrown roots, service lateral connection lines protruding into the host pipe, tar patches etc.) shall be removed. It shall be ensured that only suitable tools are used to remove such obstacles to prevent further damage to the host pipe.

Before beginning to pull in the pipe liner, it shall be ensured that the host pipe is not in service; if necessary, inflatable pipe plugs (Annex 22) and flow diverters (Annex 21) shall be inserted.

The accident prevention provisions applicable to the rehabilitation procedure shall be complied with.

Devices for the rehabilitation procedure which are to be inserted into the pipe section to be rehabilitated may only be used if tests were carried out in advance to ensure that no inflammable gases are present in the pipe section.

For this purpose, the appropriate sections of the following sets of rules shall be observed:
- GUV-R 126²⁵ (formerly GUV 17.6)
- DWA-M 149-2²⁴
- DWA-A 199-1 and DWA-A 199-2²⁶

The accuracy of the information specified in Section 3.1.1 shall be checked on-site. To this end, the section of the pipe to be rehabilitated shall be sufficiently cleaned with standard high-pressure cleaning equipment so that the damage can be readily seen on the monitor during the visual inspection in accordance with advisory leaflet DWA-M 149-2²⁴.

During entry into a manhole of the host pipe and during execution of the steps in the rehabilitation process, the relevant accident prevention provisions shall also be observed.

The steps required for the implementation of the process shall be defined for each rehabilitation project using record forms.

3.2.3.2 Incoming inspection of the process components on-site

The GRP pipe liners, delivered to site in light-proof packaging, shall be checked on-site to ensure they are not damaged and the markings specified in Section 2.2.3 exist.

²⁵ GUV-R 126 Safety regulations for working in confined spaces in sewage treatment plants (formerly GUV 17.6); issue: 2008-09
²⁶ DWA-A 199-2 German Association for Water, Wastewater and Waste (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V., DWA) - Work sheet 199: Service and operating instructions for the personnel of sewerage systems, – Part 1: Operating instructions for the personnel of sewerage plants; issue: 2011-11
3.2.3.3 Testing of the UV emitters

Brand new UV lamps shall be checked for the first time after approx. 400 hours of operation by carrying out a comparative measurement with a calibrated measuring device (Annex 30), to determine whether their radiation intensity is in the range of 8,500 W/m². After this, each lamp shall be checked at intervals of 150 operating hours.

3.2.3.4 Pulling in the PE preliners or the fibre-reinforced PVC protection tube

Before the GRP pipe liner delivered to the site in light-proof boxes can be pulled into the damaged sewer, a PE preliner foil of up to 1.5 mm thickness (Variation 1, Annex 2) shall be inserted (Annex 23). The preliner serves as a sliding film and protective foil for the insertion of the GRP pipe liner. If the PE preliner foil is used for manholes that are crossed (intermediate manholes), supporting foils which correspond to the nominal diameter of the sewer to be rehabilitated shall be placed as pipe abutments to avoid overstetching the GRP pipe liner during the subsequent pressure application (see Section 3.2.3.8).

If the sewer to be rehabilitated shows groundwater infiltrations, a fibre-reinforced PVC protection tube (Variation 2, Annex 3) shall be used instead of the PE preliner foil described above to protect the GRP pipe liner, which is not yet cured. Then the GRP pipe liner shall be pulled into this. The use of the above-mentioned supporting foils in intermediate manholes is not required if the fibre-reinforced protective PVC tube is used.

3.2.3.5 Inserting the GRP pipe liner (Annex 24)

The GRP pipe liner shall be removed from the transportation boxes in such a way that the light-protecting foil covers the pipe liner during the entire insertion period, if possible. A so-called “pull-in head” shall be formed at the end of the pipe liner, i.e. the pipe liner shall be folded lengthwise so that a pull-in rope can be fixed onto it (e.g. by means of ratchet straps).

The GRP pipe liner shall be pulled into the sewer to be rehabilitated using a cable winch, possibly with a pulley at the edge of the start manhole, and a deflection bend corresponding to the nominal diameter of the sewer to be rehabilitated. It shall be ensured that the liner is not damaged in the process. Biodegradable oil may be applied to the preliner to reduce the pulling forces. During the insertion process, it shall be ensured that the maximum pulling forces indicated in Table 1 below are not exceeded.

Table 1: "Maximum pulling forces"

<table>
<thead>
<tr>
<th>Outer diameter of the pipe liner in [mm]</th>
<th>Maximum pulling forces in [kN]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN 150</td>
<td>15</td>
</tr>
<tr>
<td>DN 200 to 250</td>
<td>30</td>
</tr>
<tr>
<td>DN 300 to DN 450</td>
<td>40</td>
</tr>
<tr>
<td>Oval profile 200/300 to 350/525</td>
<td></td>
</tr>
<tr>
<td>DN 500 to DN 690</td>
<td>90</td>
</tr>
<tr>
<td>Oval profile 400/600 to 500/750</td>
<td></td>
</tr>
<tr>
<td>DN 700 to DN 1200</td>
<td>120</td>
</tr>
<tr>
<td>Oval profile 570/860 to 900/1350</td>
<td></td>
</tr>
<tr>
<td>DN 1200 to DN 1600</td>
<td>150</td>
</tr>
<tr>
<td>Oval profile 1000/1500 to 1200/1800</td>
<td></td>
</tr>
</tbody>
</table>
If possible, the insertion process shall be conducted without stopping the winch. When pulling in the liner, swivels shall be used to ensure that the GRP pipe liner does not twist about its longitudinal axis. The pulling forces shall be recorded either in a time-continuous manner, provided that the pulling device is capable of producing greater pulling forces than the maximum permitted forces for the GRP pipe liner, see Table 1, or the set pulling forces of the pulling force restriction shall be recorded in writing. If the liner has a length of more than 40 m, the required pulling force should continue to be maintained for approx. 15 minutes after the insertion. This should prevent the GRP pipe liner from sliding back due to its elasticity and thus the creation of radial folds after the rehabilitation.

3.2.3.6 Positioning of swelling tapes (auxiliary materials)
After pulling in the pipe liner and before calibrating (inflating the GRP pipe liner), one or two profiled swelling tapes can be positioned at approx. 10 cm to 20 cm from the start of the pipe to be rehabilitated. These shall be positioned by hand (Annex 29). The positioning of the swelling tapes can also be carried out in the same manner for every manhole crossed and the end manhole.

3.2.3.7 Calibrating the GRP pipe liner
After the GRP pipe liner has been pulled in, the ends of the pipe liner shall be sealed using sealing plugs (Annexes 18 and 19, also referred to as packing). The GRP pipe liner shall be inflated by applying compressed air. The pressure of 100 mbar to 600 mbar, depending on the nominal diameter of the pipe liner (see Table 2), shall be built up as slowly as possible. Pressure stage increases of 50 mbar approx. every 5 minutes should be adhered to. After the first three pressure stage increases of 50 bar, the pressure stage increases can be stepped up to 100 mbar. After every pressure stage increase, a waiting period of approx. 5 minutes to 10 minutes should be allowed for. The overall calibrating time is approx. 30 minutes.

<table>
<thead>
<tr>
<th>Outer diameter of the pipe liner in [mm]</th>
<th>Pressure application in [mbar]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN 150 to DN 400</td>
<td>300 to 800</td>
</tr>
<tr>
<td>Oval profile 200/300 to 300/400</td>
<td></td>
</tr>
<tr>
<td>DN 450 to DN 500</td>
<td>300 to 500</td>
</tr>
<tr>
<td>Oval profile 400/600</td>
<td></td>
</tr>
<tr>
<td>DN 550 to DN 800</td>
<td>200 to 400</td>
</tr>
<tr>
<td>Oval profile 500/750 to 600/900</td>
<td></td>
</tr>
<tr>
<td>DN 900 to DN 1200</td>
<td>150 to 300</td>
</tr>
<tr>
<td>Oval profile 700/1050 to 900/1350</td>
<td></td>
</tr>
<tr>
<td>DN 1200 to DN 1600</td>
<td>100 to 250</td>
</tr>
<tr>
<td>Oval profile 1000/1500 to 1200/1800</td>
<td></td>
</tr>
</tbody>
</table>

3.2.3.8 Light-curing of the GRP pipe liner (Annex 26)
After the GRP pipe liner has been calibrated (inflated), the UV light source related to the nominal diameter shall be introduced into the GRP pipe liner (Annex 25). The light source shall be inserted at the end manhole. The pulling cable of the UV light source and the power supply cable shall be pulled through the respective openings in the sealing plug (packing in accordance with Annexes 18 and 19). When inserting the UV light source into the GRP pipe liner, it shall be ensured that the inner foil is not damaged. Afterwards, the GRP pipe liner shall be calibrated in accordance with Section 3.2.3.7.
The light source may only be switched on if there are no longer any people in the start manhole and the UV light source has been completely inserted into the GRP pipe liner. As soon as the UV light source has been switched on, it shall be pulled to the end manhole with a speed depending on the nominal diameters in accordance with the details given in Table 3.

Table 3  "Curing rate"

<table>
<thead>
<tr>
<th>Outer diameter of the pipe liner in [mm]</th>
<th>Light chain UV lamps</th>
<th>Speed 1 in [cm/min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN 150</td>
<td>chain with 4 / 6 / 8 / 9 / 10 lamps 2</td>
<td>70 - 200</td>
</tr>
<tr>
<td>DN 200</td>
<td>chain with 6 / 8 / 9 / 10 lamps 2</td>
<td>70 – 180</td>
</tr>
<tr>
<td>DN 250</td>
<td>chain with 6 / 8 / 9 / 10 lamps 2</td>
<td></td>
</tr>
<tr>
<td>DN 300</td>
<td>core with 6 lamps 2</td>
<td>40 - 100</td>
</tr>
<tr>
<td>DN 350</td>
<td>core with 6 lamps 2</td>
<td>60 - 140</td>
</tr>
<tr>
<td>DN 400</td>
<td>core with 6 lamps 2</td>
<td>40 - 100</td>
</tr>
<tr>
<td>DN 450</td>
<td>core with 6 lamps 2</td>
<td></td>
</tr>
<tr>
<td>DN 500</td>
<td>core with 6 lamps 3</td>
<td>35 - 110</td>
</tr>
<tr>
<td>DN 600</td>
<td>core with 10 lamps 2</td>
<td>35 - 80</td>
</tr>
<tr>
<td>DN 700</td>
<td>chain with 4 / 6 lamps 3</td>
<td>30 - 80</td>
</tr>
<tr>
<td>DN 800</td>
<td>core with 6 / 9 lamps 3</td>
<td></td>
</tr>
<tr>
<td>DN 900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DN 1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DN 1200</td>
<td>chain with 4 / 6 / 9 lamps 3</td>
<td>20 - 80</td>
</tr>
<tr>
<td>DN 1400</td>
<td>core with 6 / 9 lamps 3, core with 10 lamps 2</td>
<td></td>
</tr>
<tr>
<td>DN 1500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DN 1600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oval profile 200/300</td>
<td>chain with 6 / 8 / 9 / 10 lamps 2</td>
<td>70 - 160</td>
</tr>
<tr>
<td>Oval profile 250/375</td>
<td></td>
<td>60 - 130</td>
</tr>
<tr>
<td>Oval profile 300/450</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oval profile 400/600</td>
<td></td>
<td>35 - 100</td>
</tr>
<tr>
<td>Oval profile 500/750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oval profile 570/860</td>
<td>core with 6 / 9 lamps 3</td>
<td>15 - 80</td>
</tr>
<tr>
<td>Oval profile 600/900</td>
<td>core with 10 lamps 2</td>
<td></td>
</tr>
<tr>
<td>Oval profile 1000/1500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oval profile 1200/1600</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 The rate depends on the pipe geometry, the wall thickness of the GRP pipe liner, the inserted UV light sources and the prevailing conditions on the construction site (water, temperature, material of the sewer to be rehabilitated etc.). Figures indicated here are average values taken from practical experience.

2 400 W per UV lamp

3 1000 W per UV lamp, if UV light sources with Bluetec technology are used, the 1000 W lamp can also be connected with 400 "W and 600 "W lamps. (The use of the respective chain/core depends on the installation conditions, e.g. the size of the manhole.)
If the UV light sources are switched on, it shall be ensured that the minimum spacing depending on the nominal diameter in accordance with Annex 10 is maintained between the individual lamps and the inner surface of the GRP pipe liner.

The change in pressure during the light curing, the position of the UV light source, the speed of the UV light source, the functional condition of the UV lamps and the reaction temperature shall each be recorded.

During the UV light curing, heat is produced by the exothermic reaction of the resin. The resulting temperatures on the surface of the GRP pipe liner shall have a minimum temperature of +80 °C and shall not exceed a temperature level of +140 °C. The temperature level shall be continuously checked using temperature measuring probes, which are installed on the circumference, in the entry area, in the middle section and the end area near the respective UV light sources, while the light source is pulled through and the results recorded. If the surface temperature exceeds the specified level, the light source shall be moved at a slower or faster speed, making use of the entire speed range given in Table 3.

3.2.3.9 Removing the inner foil

After a cooling phase lasting a few minutes, the UV light source shall be removed from the cured GRP pipe liner. The packing shall then be taken out and then the inner foil is removed.

3.2.3.10 Leak testing of the GRP pipe liner

The leak tightness of the cured GRP pipe liner shall be checked before cutting open the lateral connections and creating the manhole connections in accordance with the criteria in DIN EN 161027 (see also Section 3.2.3.15) (Annex 33).

3.2.3.11 Finishing work

After curing and cooling, air powered cutting tools shall be used to cut off the inner pipe that has been formed in the start and end manhole with an overhang of approx. 2 cm to 3 cm width at the respective manhole wall and to remove it. In each of the intermediate manholes, the top half shell of the formed pipe shall be removed, down to the point of pipe entry at the bottom of the manhole.

Samples required for subsequent testing shall be taken from the removed pipe sections (please see Section 3.2.4).

The cutting work shall be carried out in compliance with the relevant accident prevention provisions.

3.2.3.12 Manhole connection

Watertight manhole connections shall be produced using swelling tapes (auxiliary tapes) (Annex 32) to be positioned in the manhole connection areas prior to pull-in of the PE preliner.

In the respective start manhole and, if applicable, the end manhole, as well as in the intermediate manholes, the sections of the cured inner pipe overlapping the end faces of the manholes (mirror) (see also Section 3.2.3.11) and the transitions to the flow channels in the start and end manholes shall be designed to be watertight.

In areas in which use of swelling tapes (auxiliary tapes) is structurally unfeasible, a watertight connection between the pipe liner and the manhole after curing can also be achieved in the following ways (Annex 29):
National technical approval
(allgemeine bauaufsichtliche Zulassung)/
General construction technique permit (allgemeine Bauartenehmigung)

No. Z-42.3-490

Page 19 of 23 | 24 January 2019

a) smoothing of the transitions by means of a reaction resin filler for which a national technical approval (allgemeine bauaufsichtliche Zulassung) applies,
b) smoothing of the transitions by means of mortar systems for which a national technical approval (allgemeine bauaufsichtliche Zulassung) applies,
c) GRP laminates for which a national technical approval (allgemeine bauaufsichtliche Zulassung) applies,
d) grouting with polyurethane (PU) or epoxy (EP) resins for which a national technical approval (allgemeine bauaufsichtliche Zulassung) applies,
e) installation of pipe liner end sleeves for which a national technical approval (allgemeine bauaufsichtliche Zulassung) applies.

It shall be ensured that the watertight transitions are properly executed.

3.2.3.13 Restoring residential connections

Following curing, the service laterals shall be cut open using camera-monitored pneumatic or hydraulic milling robots. Residential connections can be restored by means of robot technology (top hat technique, Annex 31) or in an open construction or by means of a renovation or rehabilitation method (e.g. grouting technique) for which the national technical approvals (allgemeine bauaufsichtliche Zulassungen) apply.

3.2.3.14 Labelling in the manhole

The following information shall be marked in a durable and easily legible manner in the start or end manhole for the rehabilitation measure:

- Type of rehabilitation
- Designation of pipe section
- Nominal size
- CIPP liner wall thickness
- Year of rehabilitation

3.2.3.15 Final inspection and leak testing

After the work has been completed, the rehabilitated pipe section shall be visually inspected. It shall be ensured that all residual materials have been removed and no hydraulically disadvantageous wrinkles are present. There shall be no exposed glass fibres. After curing of the pipe liner, including creation of the manhole connections and reinstatement of the residential connections, leak testing shall be carried out (Annex 33). This can also be done section-wise.

The tightness of the rehabilitated pipes shall be tested before the residential connections are opened using water ("W" procedure) or air ("L" procedure) in accordance with DIN EN 161027. Testing with air shall be carried out in compliance with the specifications in Table 3 of DIN EN 161027, test procedure 'LB' for dry concrete pipes. Rehabilitated residential connections using the top hat technique can also be checked separately using suitable inflatable pipe plugs to determine whether they are watertight.

3.2.4 Testing of samples

3.2.4.1 General

On the construction site, circular rings or segments shall be taken from the cured circular or approximately circular GRP pipe liners for oval-shaped profiles (Section 3.2.3.11). When taking samples of segments from circular profiles, it shall be observed whether they are taken from the area of the springer or the area of the base/apex. A "pull strap" is located in both the base and apex areas (Section 3.1.2.1.1). The respective mechanical characteristics in accordance with Section 3.1.2.1.3 shall be observed.
If the sample pieces taken for the named tests are found to be unsuitable, the tests on the properties to be complied with can be carried out on samples taken directly from the cured pipe liner (Annex 34).

For pipe liners with oval-shaped cross-sections, the samples shall be taken from the area with the largest buckling load, in the area of the cross-section between 3:00 and 5:50 o'clock (It shall be ensured that no samples are taken in the area where the "pull strap" is located (Section 3.1.2.1.1)).

The sampling point of sewers with oval-shaped cross-sections with width/height dimensions ≥ 600 mm / 900 mm shall then be resealed using hand-applied laminate with the same wall thickness.

3.2.4.2 Strength properties
The modulus of elasticity and the bending strength $\sigma_{fb}$ shall be determined on the obtained samples. In these tests, the 1 minute value, the 1 hour value and the 24 hour value of the modulus of elasticity in bending and the 1 minute value of the bending strength $\sigma_{fb}$ shall be recorded.

During the test it shall also be determined whether the creep tendency (area of the springer, as well as base and apex areas) based on DIN EN ISO 899-228 for the pipe liner

1. "Brandenburger Liner BB 1.0" DN 150 to DN 300 with glass/polyester fleece mats and with UP resin

$k_n \leq 16.6\%$

2. "Brandenburger Liner BB 2.0" DN 150 to DN 1600 with glass fibre tubes and with UP resin

$k_n \leq 10.6\%$ (after a sample age of 7 days) and

$k_n \leq 10.2\%$ (after a sample age of 14 days) and

$k_n \leq 8.6\%$ (after a sample age of 28 days) as well as

3. "Brandenburger Liner BB 2.5" DN 150 to DN 1600 with glass fibre tubes and with UP and VE resin

$k_n \leq 9.6\%$ (after a sample age of 7 days) and

$k_n \leq 8.4\%$ (after a sample age of 14 days) and

$k_n \leq 6.7\%$ (after a sample age of 28 days)

is complied with in accordance with the following ratio:

$$K_n = \frac{E_{th} - E_{24h}}{E_{th}} \times 100$$

The test on circular segments shall be carried out using the three-point loading test method in accordance with DIN EN ISO 11296-42 or DIN EN ISO 17817. Curved test rods from the respective circular cross-section are to be used, which have been taken from the segments in a radial direction with a minimum width of 50 mm. In the test and the calculation of the modulus of elasticity, the measured support span between the supports for the sample shall be considered.

The determined short-term values for the bending strength $\sigma_{fb}$ and the modules of elasticity (1 minute values) shall be equal to or greater than the values specified in Sections 3.1.2.1.3 or 3.1.2.1.4.
When changing the resin supplier, a full circular ring (pipe section) shall also be removed from the cured tube. This shall be used to test the ring stiffness. In this test, the 1 minute value, the 1 hour value and the 24 hour value of the ring stiffness shall be recorded. The ring stiffness shall be tested in accordance with the method described in DIN 53769-3\textsuperscript{29}, including the creep tendency.

### 3.2.4.3 Watertightness

The watertightness of the cured GRP pipe liner shall be tested on samples obtained from the cured pipe liner without preliner and without foil coating, based on the criteria given in DIN EN 1610\textsuperscript{27}. Testing of samples can be carried out with an overpressure or an underpressure of 0.5 bar. For the underpressure test one side of the sample shall be exposed to water. At an underpressure of 0.5 bar no water may be observed to exit from the sample side not exposed to water over a test duration of 30 minutes. In the overpressure test, a water pressure of 0.5 bar shall be applied for a duration of 30 minutes. With this method as well no water may be observed to exit from the side of the sample not exposed to water.

### 3.2.4.4 Density

The density of the sample taken from the cured pipe liner without preliner and without foil coating shall be tested, for example in accordance with DIN EN ISO 1183-2\textsuperscript{30}. It shall be assessed whether the density of the cured GRP pipe liner set out in Section 3.1.2.1.3 is complied with.

### 3.2.4.5 Wall thickness and structure

The average and overall wall thickness as well as the wall structure in accordance with the conditions given in Section 3.1.2.1.1 shall be checked on cut surfaces, e.g. using a light microscope at a magnification of approximately 10X. The thickness of the pure resin layer shall also be checked. The mean area fraction of voids shall also be determined in accordance with DIN EN ISO 7822\textsuperscript{30}.

### 3.2.4.6 Glass fibre content / resin content

The glass fibre content and the resin content shall be checked in accordance with the specifications given in Section 3.1.2.1.3 following DIN EN ISO 1172\textsuperscript{19}.

### 3.2.5 Declaration of conformity for the rehabilitation measures carried out

The confirmation of conformity of the executed rehabilitation work with the provisions of this general construction technique permit (allgemeine Bauartgenehmigung) shall be provided by the executing company by means of a declaration of compliance based on the specifications given in Tables 4 and 5. The declaration of compliance shall be accompanied by documents providing data on the characteristics of the process components in accordance with Section 2.1.1 and the results of the tests specified in Table 4 and Table 5.

The rehabilitation project manager or a competent representative of the manager shall be present at the construction site during execution of the rehabilitation work. They shall ensure that the work is carried out properly in accordance with the provisions of Section 3.2 and, in particular, carry out or organise the tests in accordance with Table 4 and organise the tests in accordance with Table 5. The number and scope of the tests listed there are minimum requirements.

\textsuperscript{29} DIN 53769-3 \hspace{1cm} Testing of glass fibre reinforced plastics pipes; determination of initial and long-term ring stiffness; issue: 1988-11

\textsuperscript{30} DIN EN ISO 7822 \hspace{1cm} Textile glass reinforced plastics – Determination of void content – Loss on ignition, mechanical disintegration and statistical counting methods (ISO 7822:1990); German version EN ISO 7822:1999; issue: 2000-01
The tests on test pieces in accordance with Table 5 shall be performed by an inspection body approved by the building control authorities (see list of testing, inspection and certification bodies in accordance with the Building Codes of the federal states (Landesbauordnungen) part V, no. 9).

Once in half a year, samples shall be obtained from a pipe liner from a completed rehabilitation project by the above-mentioned inspection body. This body shall also check the documentation of the tests carried out in accordance with Table 4 for the rehabilitation measure.

Table 4: ‘Process-accompanying tests’

<table>
<thead>
<tr>
<th>Subject of test</th>
<th>Nature of requirement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual inspection of pipe</td>
<td>as per Section 3.2.3.1 and DWA-M 149-2³⁴</td>
<td>prior to each rehabilitation</td>
</tr>
<tr>
<td>Visual inspection of pipe</td>
<td>as per Section 3.2.3.15 and DWA-M 149-2³⁴</td>
<td>after each rehabilitation</td>
</tr>
<tr>
<td>Equipment requirements</td>
<td>as per Section 3.2.2</td>
<td></td>
</tr>
<tr>
<td>Marking of containers for rehabilitation components</td>
<td>as per Section 2.2.3</td>
<td>each building site</td>
</tr>
<tr>
<td>Pulling forces</td>
<td>as per Section 3.2.3.5</td>
<td></td>
</tr>
<tr>
<td>Internal pressures during inflation</td>
<td>as per Section 3.2.3.7</td>
<td></td>
</tr>
<tr>
<td>Temperature level and speed of the UV light source</td>
<td>as per Section 3.2.3.8</td>
<td></td>
</tr>
<tr>
<td>State of the UV lamps</td>
<td>as per Section 3.2.3.3</td>
<td></td>
</tr>
<tr>
<td>Airtightness and/or watertightness</td>
<td>as per Section 3.2.3.15</td>
<td></td>
</tr>
</tbody>
</table>

The tests specified in Table 5 shall be organised by the rehabilitation project manager or a competent representative of the manager. For the tests specified in Table 5, samples shall be obtained from the cured GRP pipe liners. The test results shall be recorded and evaluated. They shall be submitted to Deutsches Institut für Bautechnik upon request.

Table 5: ‘Tests on samples’

<table>
<thead>
<tr>
<th>Subject of test</th>
<th>Nature of requirement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term modulus of elasticity in bending, short-term bending stress σfₘ and creep tendency at pipe cut-outs or circular rings</td>
<td>as per Sections 3.2.4.1 and 3.2.4.2</td>
<td>for every building site, min. every second pipe liner</td>
</tr>
<tr>
<td>Density and glass content of sample without preliner and without foil coating</td>
<td>as per Sections 3.1.2.1.3, 3.2.4.4 and 3.2.4.6</td>
<td></td>
</tr>
<tr>
<td>Watertightness of sample without preliner and without foil coating</td>
<td>as per Section 3.2.4.3</td>
<td></td>
</tr>
<tr>
<td>Wall structure</td>
<td>as per Sections 3.1.2.1.1 and 3.2.4.5</td>
<td></td>
</tr>
<tr>
<td>Subject of test</td>
<td>Nature of requirement</td>
<td>Frequency</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Short-term modulus of elasticity (short-term ring stiffness) and creep tendency at pipe sections or pipe cut-outs</td>
<td>as per Sections 3.1.2.1.3 and 3.2.4.2</td>
<td>with each change of the resin supplier with declaration of the resins</td>
</tr>
<tr>
<td>Resin identity by means of IR spectroscopy</td>
<td>as per Section 2.1.1</td>
<td></td>
</tr>
<tr>
<td>Creep tendency at pipe sections or cut-outs</td>
<td>as per Section 3.2.4.2</td>
<td>if short-term modulus of elasticity is less than that specified in Section 3.1.2.1.4 and at least 1 liner every six months</td>
</tr>
</tbody>
</table>

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Head of Section