

TEST REPORT: PA 0501

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Originator: **KARL OTTO BRAUN KG**
Lauterstraße 50

67752 Wolfstein

Test assignment No: **PA 0501**

Name of test assignment: **DIBt approval for BRAWOLINER**

Name of originator: -

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This report consists of 12 pages.

The test results relate only to the items tested. Extracts from this test report may only be copied with the written permission of IKT – Institute for Underground Infrastructure, Germany.

Dipl.-Ing. D. Homann
(Test centre director)

Dipl.-Ing. S. Kötters
(Project leader)

Samples

Designation of sample			Received on	Sample prepared by	Description of item in sample
Doc. no.	IKT (Test centre)	client			
1	B1003-1.1 and -1.2	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	13.10.03	client	Renovated sectioned DN 200 vitrified clay pipe pieces
	B1003-1.3 to -1.5	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	13.10.03	client	Prototype pipe
	B1003-1.6 to -1.7	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	13.10.03	client	Renovated sectioned DN 200 vitrified clay pipe pieces
	B1003-1.8 to -1.10	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	13.10.03	client	Prototype pipe
	B1003-1.11 to -1.20	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	13.10.03	client	Prototype pipe
	B1003-1.21 to -1.25	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	13.10.03	client	Prototype pipe
	B1003-1.26	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	13.10.03	client	Prototype pipe
	B1003-1.27 to -1.29	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	13.10.03	client	Prototype pipe
2	B1114-1 to -3	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	16.03.04	client	Prototype pipe

Illustration of sample items as supplied:



Figure 1: Sample item B1003-1 as supplied



Figure 2: Sample item B1003-1 as supplied

Tests carried out

Number	Type of test	Testing specification	Test sample No.	Preparation of test sample
10	Adhesive pull test	Based on ZTV SIB 90	B1003-1.6 and -1.7	-
3	Short-time apex pressure trial	Based on DIN EN 1228	B1114-1 to -3	-
3	Determination of creep ratio	Based on DIN EN 16869 Part 2	B1114-1 to -3	-
8	3-point bending test	Based on DIN EN ISO 178	B1003-1.21 to -1.28	Sawn-off piece of prototype pipe
6	Resistance against chemical attack	Based on DIN EN ISO 175	B1061-1.1 to -1.7	Sawn-off piece of prototype pipe
2	Leak testing	*)	B1003-1.26	Sawn-off piece of prototype pipe
3	Determination of density	Based on DIN 53479	B1003-1.27 to -1.29	Sawn-off piece of prototype pipe
2	Darmstadt trough test	Based on DIN 19565-1	B1003-1.1 and -1.2	-
3	Long-time apex pressure trial	Based on EN 761	B1114-1 to -3	-

***) Testing specification for leak testing on liner pieces:**

The reverse of a piece of liner is pressed against the seal of a flask and a vacuum pump is then used to produce a 500-mbar vacuum inside the flask. The piece of liner is then sprinkled with reddened water on its inside. The vacuum is maintained for 30 minutes. Provided there is no reddened water at the bottom of the flask at the end of the test period, the liner is held to be waterproof.

Test results

The test results are to be found in the following tables.

Adhesive pull test

(ZTV SIB 90)

IKT sample designation WEB No.	Description of sample	Adhesive pull test [N/mm ²]		
		Individual value	Location of break	Mean value
B1003-1.6	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	2.54	In the adhesive	1.55
		0.82	In the adhesive	
		4.64	In the subsurface	
		3.45	In the subsurface	
		2.86	In the subsurface	
B1003-1.7	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	0.20	At the bonding point	
		0.26	At the bonding point	
		0.32	At the bonding point	
		0.20	At the bonding point	
		0.20	At the bonding point	

Illustration of test areas for adhesive pull test:



Figure 3: Test area 1 on sample item B1003-1.6



Figure 4: Test area 2 on sample item B1003-1.6



Figure 5: Test area 3 on sample item B1003-1.6



Figure 6: Test area 4 on sample item B1003-1.6



Figure 7: Test area 5 on sample item B1003-1.6



Figure 8: Test area 1 on sample item B1003-1.7



Figure 9: Test area 2 on sample item B1003-1.7



Figure 10: Test area 3 on sample item B1003-1.7



Figure 11: Test area 4 on sample item B1003-1.7



Figure 12: Test area 5 on sample item B1003-1.7

Short-time apex pressure trial:

Initial specific ring stiffness S_0 and modulus of elasticity (DIN EN 1228)

IKT sample designation	client sample designation	Nominal diameter	Mean modulus of elasticity value	Mean S_0 value
WEB No.		[mm]	[N/mm ²]	[N/mm ²]
B1114-1	Brawoliner Fabric: polyester Resin: Brawoliner [®] - resin	DN 200	2.916	0.002998
B1114-2	Brawoliner Fabric: polyester Resin: Brawoliner [®] - resin	DN 200	2.887	0.003685
B1114-3	Brawoliner Fabric: polyester Resin: Brawoliner [®] - resin	DN 200	2.646	0.003581
Mean value:			2.816	0.003421

Determination of creep ratio K_N

(Based on DIN EN 16869 Part 2)

IKT sample designation	client sample designation	Nominal diameter	E_{1h}	E_{24h}	K_N
WEB No.		[mm]	[N/mm ²]	[N/mm ²]	[mm]
B1114-1	Brawoliner Fabric: polyester Resin: Brawoliner [®] - resin	DN 200	2.526	2.358	6.64
B1114-2	Brawoliner Fabric: polyester Resin: Brawoliner [®] - resin	DN 200	2.831	2.645	6.57
B1114-3	Brawoliner Fabric: polyester Resin: Brawoliner [®] - resin	DN 200	2.654	2.479	6.61
Mean value:			2.670	2.494	6.61

3-point longitudinal bending test:

Bending tensile strength and modulus of elasticity (DIN EN ISO 178)

IKT sample designation	client sample designation	Nominal diameter	Mean modulus of elasticity value	Mean value β_{BT}	Mean sample thickness
WEB No.		[mm]	[N/mm ²]	[N/mm ²]	[mm]
B1003-1.21 to -1.28	Brawoliner Fabric: polyester Resin: Brawoliner [®] - resin	DN 200	2.119	44.29	4.60

Resistance to chemical attack
(Based on DIN EN ISO 175)

The chosen test media were a 10% solution of sulphuric acid (H₂SO₄) and a 10% peroxide solution. The sample items were stored at 22°C for seven days and then dried in a warming cabinet (2 hours at 50°C). The sample item B 1061-1.7 was stored for the same period in tap water at 22°C for use as a reference sample.

Visual assessment of changes in colour in the sample items to DIN EN ISO 175, Table 1:

IKT sample item designation	Test medium	Test period and temperature	Colour changes
B1061-1.1	10% H ₂ SO ₄	7 d, 22°C	None
B1061-1.2	10% H ₂ SO ₄	7 d, 22°C	None
B1061-1.3	10% H ₂ SO ₄	7 d, 22°C	None
B1061-1.4	10% Peroxide	7 d, 22°C	None
B1061-1.5	10% Peroxide	7 d, 22°C	None
B1061-1.6	10% Peroxide	7 d, 22°C	None
B1061-1.7	100% H ₂ O	7 d, 22°C	None

Table 1 from DIN EN ISO 175

Assessment of qualitative changes
None
Hardly detectable
Small
Medium
Very obvious



Figure 13: Illustration of sample items B1061-1.1 to -1.3 (sulphuric acid) after drying



Figure 14: Illustration of sample items B1061-1.4 to -1.6 (peroxide) after drying

Change in sample mass:

Stored in 10% sulphuric acid:

IKT sample item designation	Percentage mass change	
	Immediately on removal	After removal and drying
B1061-1.1	1.57	0.64
B1061-1.2	1.47	0.57
B1061-1.3	1.72	0.57

Stored in 10% peroxide solution:

IKT sample item designation	Percentage mass change	
	Immediately on removal	After removal and drying
B1061-1.4	0.61	-0.11
B1061-1.5	0.46	-0.10
B1061-1.6	0.58	-0.08

Stored in tap water:

IKT sample item designation	Percentage mass change	
	Immediately on removal	After removal and drying
B1061-1.7	0.59	-2.34

Once testing is complete, visual inspection shows that storage in 10% sulphuric acid (H₂SO₄) and in 10% peroxide solution does not lead to any colour change in the resin. The change in weight observed after storage in sulphuric acid is less than 0.65% and in the case of the peroxide solution -0.11 %, this being measured in each case after removal and drying. These values may be regarded as negligible. No visible swelling of the sample items was observed.

Leak testing:

IKT sample designation WEB No.	client sample designation	Test period [min]	Negative pressure [mbar]	Number of water droplets in flask	Result
B1003-1.26	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	30	500	0	Waterproof

Determination of density

(Based on DIN 53479):

IKT sample designation WEB No.	client sample designation	Density [g/cm ³]	Average density [g/cm ³]
B1003-1.27	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	1.164	1.164
B1003-1.28	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	1.164	
B1003-1.29	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	1.163	

Abrasion test with Darmstadt trough

IKT sample designation WEB No.	client sample designation	Nominal diameter [mm]	Maximum abrasion [mm] Number of load alternations		
			50,000	100,000	200,000
B1003-1.1	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	DN 200	0.11	0.28	0.33
B1003-1.2	Brawoliner Fabric: polyester Resin: Brawoliner® - resin	DN 200	0.09	0.38	0.41

On completion of the abrasion tests with 200,000 load alternations, the liner samples showed no evidence of changes to the upper surface. Figures 15 and 16 show the abraded inner surfaces of the sample items after 200,000 load alternations.



Figure 15: Sample item B1003-1.1 after the abrasion test with 200,000 load alternations



Figure 16: Sample item B1003-1.2 after the abrasion test with 200,000 load alternations

Long-term peak compressive test

(in accordance with DIN EN 761)

- Specimens B1114-1 to -3 were tested in an air-conditioned testing laboratory at 23 °C ($\pm 1^\circ\text{C}$) and 50% ($\pm 5\%$) relative humidity.
- The initial ring rigidity and short-term E-module were determined in accordance with DIN EN 1228 in order to ascertain the load in the long-term peak compressive test.
- On 22nd March 2004, the long-term peak compressive test began in accordance with DIN EN 761. After an exposure period of 10,000 hours, the test ended on 13th May 2005.



Fig. 17: Test station for the long-term peak compressive test in the IKT.

Comments on the test evaluation:

Extrapolating the measured distortion level may, in accordance with DIN EN 761, be undertaken over a period of 50 years using a first degree polynomial. However, this presupposes the data extrapolation capacity is monitored in accordance with DIN EN 705, paragraph 3.1.3. The evidence of this is demonstrated provided that the stated value, $M > 0$ (see equation 1) the stability index r^2 and the correlation coefficient r all lie above a limiting value. All these prerequisites have been fulfilled in the case of the following extrapolations, meaning that an extrapolation based on method B cited in DIN EN 705 is permissible in accordance with the first degree polynomial.

$$M = \frac{S_x^2}{S_{xy}^2} - \frac{t_v^2 (S_x S_y - S_{xy}^2)}{(n-2)S_y^2} \quad (\text{equation 1})$$

Test results

After a 10,000 hour exposure period, no visual damage could be ascertained to the hose liners B1114-1 to B1114-3. The test results obtained from the long-term peak compressive are displayed in the following table and diagrams.

IKT sample designation	client sample designation	3 minutes short-term-E module	Initial ring rigidity S_0	24 hours creep tendency K_N	1,000 hours E module	2,000 hours E module	5,000 hours E module	10,000 hours E module	Extrapolated E-module at 438,000 hours (= 50 years)	A_{50a}
WEB no.		[N/mm ²]	[-]	[%]	[N/mm ²]	[N/mm ²]	[N/mm ²]	[N/mm ²]	[N/mm ²]	[-]
B1114-1	Brawoliner Material: Polyester Resin: Brawoliner® - resin Diameter: DN 200	2.916	0.002998	5.93	2.475	2.318	2.178	2.112	1.886	1.56
B1114-2	Brawoliner Material: Polyester Resin: Brawoliner® - resin Diameter: DN 200	2.887	0.003685	5.03	2.396	2.338	2.253	2.208	2.015	1.45
B1114-3	Brawoliner Material: Polyester Resin: Brawoliner® - resin Diameter: DN 200	2.646	0.003581	4.48	2.159	2.128	2.039	2.008	1.866	1.33
	Median	2.816	0.003421	5.18	2.343	2.261	2.156	2.115	1.922	1.45