Three-point bending test on CIPP liners

Five companies qualify for the '100% Club'

There were excellent CIPP liner results for the individual test criteria, but only one in four of the rehabilitation contractors succeeded in a 100% pass on all tests conducted on their samples. However, five years ago this figure was only one in five, so the overall trend is upward.

by Roland W. Waniek, Dieter Homann and Barbara Grunewald

IKT - Institute for Underground Infrastructure presents its 13th annual LinerReport. This is based on 1,845 CIPP liner samples taken on sites for Quality Control purposes during 2016 and tested by the IKT CIPP Liner Test Centre.

The 2016 database

This 2016 IKT LinerReport presents the test results obtained by twenty-two rehabilitation contractors. For each, a minimum of twenty-five samples of one type of liner, taken from at least five different rehabilitation sites, were submitted to IKT. These companies used seven different liner systems and in two cases contractors entered samples for two different systems. The results are presented for four test criteria and performance is compared between rehabilitation contractors and type of liner.

Twelve of the contractors are active in Germany, four in the Netherlands, two each in Belgium and Austria, one in Switzerland and one in the Czech Republic. Swietelsky-Faber is represented by separate, legally independent companies in Germany, Netherlands and Austria, and so appears as three different companies in this LinerReport. In two thirds of cases, the project clients (or their engineering consultancies) commissioned IKT directly to perform laboratory tests on their liner samples. The remaining one third of the orders originated from contractors themselves (see Table 1).

Target performance data vs Actual data from tests

The four characteristics for each of the samples that are tested and assessed for the Liner-

continued page 4

Table 1: Number of samples submitted for each contractor and liner system, 2016

Contractor and country (Germany unless indicated in brackets)	Liner systems	Liner-type	No. of samples	IKT testing commissioned by	
				Contractor %	Client %
Aarsleff Rohrsanierung GmbH	iMPREG liner	GRP	118	0.8	99.2
Aarsleff Rohrsanierung GmbH	PAA SF liner	NF	92	0.0	100.0
Arkil Inpipe GmbH	Berolina liner	GRP	41	0.0	100.0
Arkil Inpipe GmbH	SAERTEX liner	GRP	82	0.0	100.0
Braumann Tiefbau GmbH (**A**)	Berolina liner	GRP	28	0.0	100.0
Geiger Kanaltechnik GmbH & Co.KG	Brandenburger liner	GRP	34	55.9	44.1
GMB Rioleringstechnieken B.V. (**NL**)	SAERTEX liner	GRP	134	13.4	86.6
Hamers Leidingtechniek B.V. (**NL**)	Alphaliner	GRP	105	0.0	100.0
Insituform Rioolrenovatietechnieken B.V. (**NL**)	Insituform CIPP liner (NL)	NF	149	3.4	96.6
ISS Kanal Services AG (**CH**)	Alphaliner	GRP	41	65.9	34.1
Jeschke Umwelttechnik GmbH	Brandenburger liner	GRP	120	89.2	10.8
Kanaltechnik Agricola GmbH	iMPREG liner	GRP	37	100.0	0.0
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	GRP	52	0.0	100.0
KTF GmbH	iMPREG liner	GRP	94	96.8	3.2
Kumpen N.V. (**B**)	Brandenburger liner	GRP	58	53.4	46.6
Max Bögl Stiftung & Co. KG	Brandenburger liner	GRP	46	0.0	100.0
Renotec N.V. (**B**)	SAERTEX liner	GRP	29	0.0	100.0
RTi Germany GmbH	SAERTEX liner	GRP	50	68.0	32.0
Swietelsky-Faber Kanalsanierung GmbH (**A**)	Brandenburger liner	GRP	30	0.0	100.0
Swietelsky-Faber Kanalsanierung GmbH (**D**)	Berolina liner	GRP	38	0.0	100.0
Swietelsky-Faber Nederland Relining B.V. (**NL**)	iMPREG liner	GRP	47	0.0	100.0
TKT GmbH &Co.KG	Alphaliner	GRP	168	36.9	63.1
Trasko a.s. (**CZ**)	Alphaliner	GRP	72	100.0	0.0
Umwelttechnik und Wasserbau GmbH	Alphaliner	GRP	180	53.3	46.7
Total			1 845	**32.5**	**67.5**

GRP: Glass-fibre backing material
NF: Needle-felt backing material

Overview of test and inspection criteria

Modulus of elasticity (short-term flexural modulus)
- CIPP-liners must withstand loads such as those caused by groundwater, road traffic and soil pressure
- The modulus of elasticity is an indicator of load-bearing capability
- Stability may be endangered if modulus of elasticity is too low
- Test method: Three-point bending test in acc. with DIN EN ISO 178 and DIN EN ISO 11296-4

> Results: see Table 2

Wall thickness (average combined thickness)
- Minimum values are specified in the structural-analysis calculation
- Wall thickness and modulus of elasticity jointly determine the stiffness of the liner
- Excessively low wall thickness can endanger stability
- Test method: Average combined thickness is measured in acc. with DIN EN ISO 11296-4

> Results: see Table 4

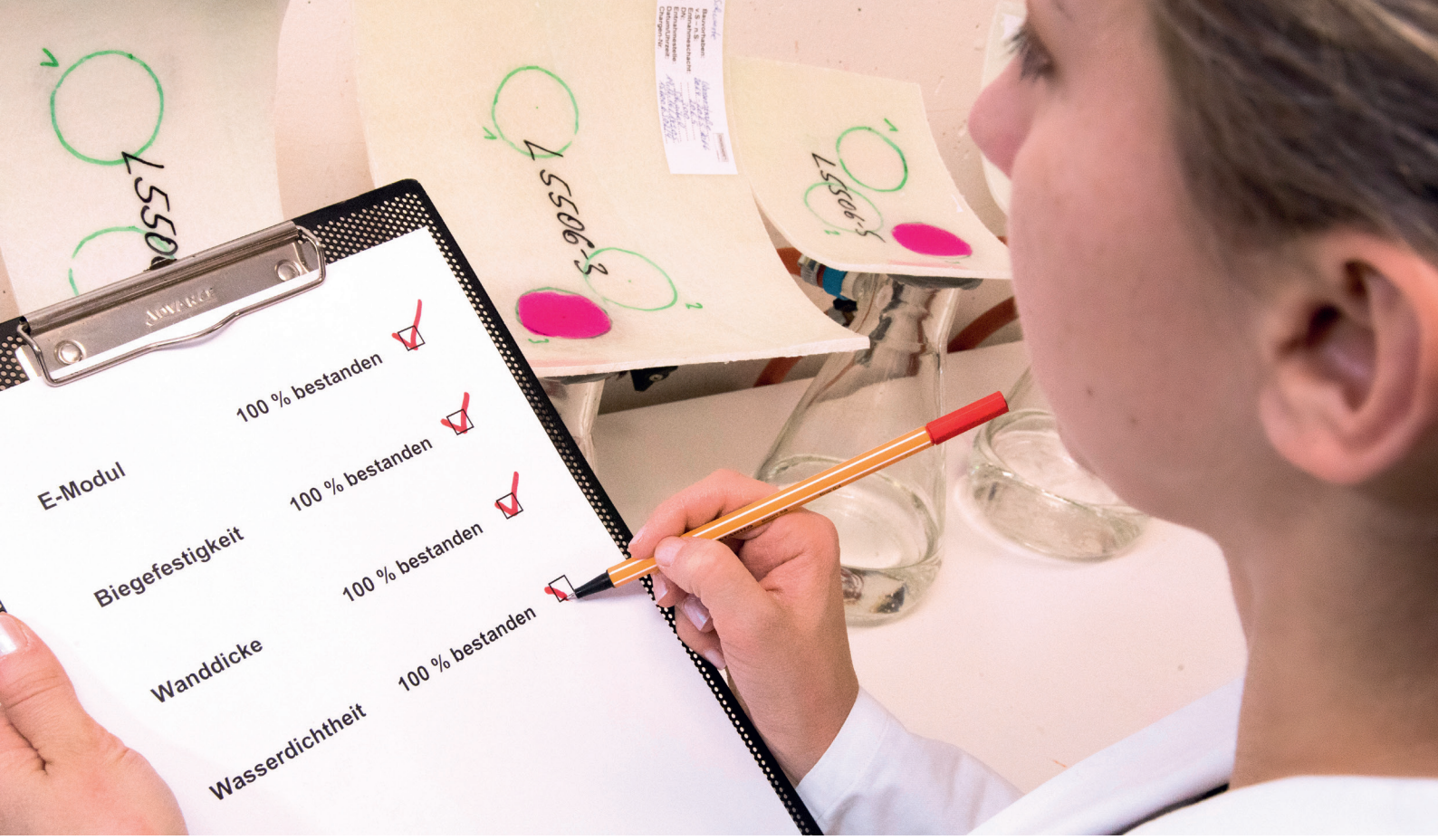
Flexural strength (flexural stress at rupture = short-term -σ_{fb})
- This denotes the point at which the liner fails as a result of excessively high stress
- The liner may rupture before the permissible deformation is reached if flexural strength is too low
- Test method: Increase of load up to failure in the three-point bending test in acc. with DIN EN ISO 178 and DIN EN ISO 11296-4

> Results: see Table 3

Water tightness
- The inner film is cut if it is not an integral component of the liner; any outer film is removed
- Water containing a red dye is applied internally
- A 0.5 bar partial pressure is applied externally
- The liner is "Not tight" if water penetrates through
- Test period: 30 min.

> Results: see Table 5

A detailed description of these tests can be found on the IKT Homepage: **www.ikt-online.org/cipp-liner**



Top performer: all four test criteria met by 100% of samples

Table 2: Test results for modulus of elasticity, 2016 (short-term flexural modulus)

Contractors and countries (Germany unless indicated in brackets)	Liner systems	2016		2015	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Aarsleff Rohrsanierung GmbH	iMPREG liner	118	100	100	↔
Arkil Inpipe GmbH	Berolina liner	41		100	↔
Arkil Inpipe GmbH	SAERTEX liner	82		95.3	↑
Braumann Tiefbau GmbH (**A**)	Berolina liner	28		-	-
Hamers Leidingtechniek B.V.(**NL**)	Alphaliner	105		100	↔
ISS Kanal Services AG (**CH**)	Alphaliner	41		100	↔
Jeschke Umwelttechnik GmbH	Brandenburger liner	120		100	↔
Kanaltechnik Agricola GmbH	iMPREG liner	37		100	↔
KTF GmbH	iMPREG liner	94		100	↔
Kumpen N.V. (**B**)	Brandenburger liner	58		-	-
RTi Germany GmbH	SAERTEX liner	50		-	-
Swietelsky-Faber Kanalsanierung GmbH (**D**)	Berolina liner	38		-	-
Swietelsky-Faber Nederland Relining B.V. (**NL**)	iMPREG liner	47		-	-
Trasko a.s. (**CZ**)	Alphaliner	72		100	↔
TKT GmbH & Co.KG	Alphaliner	168	99.4	99.6	↓
Umwelttechnik und Wasserbau GmbH	Alphaliner	180	98.9	100	↓
Average			**98.9**	**99.1**	↓
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner r	52	98.1	100	↓
Max Bögl Stiftung & Co. KG	Brandenburger liner	46	97.8	-	-
Geiger Kanaltechnik GmbH & Co.KG	Brandenburger liner	34	97.1	-	-
GMB Rioleringstechnieken B.V. (**NL**)	SAERTEX liner	134	97.0	-	-
Aarsleff Rohrsanierung GmbH	PAA SF liner	92	96.7	99.1	↓
Swietelsky-Faber Kanalsanierung GmbH (**A**)	Brandenburger liner	30	96.7	100	↓
Insituform Rioolrenovatietechnieken B.V. (**NL**)	Insituform CIPP liner (NL)	147	96.6	95.3	↑
Renotec N.V. (**B**)	SAERTEX liner	29	96.6	-	-

* Target values in accordance with client's data (structural-analysis/sample data record)
– Not evaluated, too few liner samples

Table 3: Test results for flexural strength, 2016 (short-term -σ_{fb})

Contractors and countries (Germany unless indicated in brackets)	Liner systems	2016		2015	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Arkil Inpipe GmbH	Berolina liner	41	100	100	↔
Braumann Tiefbau GmbH (**A**)	Berolina liner	28		-	-
Hamers Leidingtechniek B.V.(**NL**)	Alphaliner	105		100	↔
ISS Kanal Services AG (**CH**)	Alphaliner	41		100	↔
Jeschke Umwelttechnik GmbH	Brandenburger liner	120		100	↔
Kanaltechnik Agricola GmbH	iMPREG liner	37		100	↔
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	52		100	↔
KTF GmbH	iMPREG liner	94		100	↔
Kumpen N.V. (**B**)	Brandenburger liner	58		-	-
Max Bögl Stiftung & Co. KG	Brandenburger liner	46		-	-
RTi Germany GmbH	SAERTEX liner	50		-	-
Swietelsky-Faber Kanalsanierung GmbH (**A**)	Brandenburger liner	30		100	↔
Swietelsky-Faber Kanalsanierung GmbH (**D**)	Berolina liner	38		-	-
Swietelsky-Faber Nederland Relining B.V. (**NL**)	iMPREG liner	47		-	-
TKT GmbH &Co.KG	Alphaliner	168		100	↔
Trasko a.s. (**CZ**)	Alphaliner	72		100	↔
Average			**98.4**	**99.3**	↓
Insituform Rioolrenovatietechnieken B.V. (**NL**)	Insituform CIPP liner (NL)	147	98.0	97.2	↑
Aarsleff Rohrsanierung GmbH	PAA SF liner	92	97.8	97.4	↑
Aarsleff Rohrsanierung GmbH	iMPREG liner	118	97.5	100	↓
Geiger Kanaltechnik GmbH & Co.KG	Brandenburger liner	34	97.1	-	-
Arkil Inpipe GmbH	SAERTEX liner	82	96.3	98.4	↓
GMB Rioleringstechnieken B.V. (**NL**)	SAERTEX liner	134	96.3	-	-
Umwelttechnik und Wasserbau GmbH	Alphaliner	180	95.0	98.8	↓
Renotec N.V. (**B**)	SAERTEX liner	29	86.2	-	-

* Target values in acc. with client's data (structural-analysis/sample data record)
– Not evaluated, too few liner samples

Report are: modulus of elasticity, flexural strength, wall thickness and water-tightness (see box and/or www.ikt-online.org/cipp-liner for further details). The Actual data obtained from the tests is compared against Target performance data. These are determined for the liner sample either from the liner's DIBt (German Institute for Building Technology) approval specification or against any divergent Target specifications that were required by the by the client for the particular installation. The Target values for wall thickness are either defined on the basis of structural-analysis calculations or are as specified by the client.

Two procedures are used for testing the water-tightness of needle-felt liners: one involving cutting the inner film and the other without cutting it. The film is not cut if the liner has a DIBt approval or KOMO Foundation certificate for the Netherlands that confirms that the inner film as an integral element of the system and it is intended to influence on water tightness. This applies to all samples of needle-felt liners in this Liner Report. GRP liners do not have an inner film which remains in the sewer and are tested without cutting.

Modulus of elasticity was very good

The modulus of elasticity is an indication of the load-bearing capacity of liners. The average score per contractor for samples that passed the test was 98.9%, only slightly below the 99.1% achieved in 2015. Most contractors achieved extremely good results for this test with thirteen achieving 100%. However, five companies performed less well than in the previous year (see Table 2).

Slightly poorer performance on flexural strength

The average for tests passed for flexural strength - the point at which a liner fails due to excessive stress – was 0.9 % percentage points (%P) lower than in the previous year. However, at 98.4% the average remains at a very high level. A total of sixteen companies achieved 100% pass, while three contractors had lower scores than the previous year (see Table 3).

Improvement in wall thickness, but wide variation in contractor performance

Among the four test criteria, wall thickness traditionally produces the poorest test results. 2016 was no exception, with an average of 96.2% of the liner samples passing this test. Nonetheless this was a small rise, of

Table 4: Test results for wall thickness, 2016
(average combined thickness in acc. with DIN EN ISO 11296, Part 4)

Contractors and countries (Germany unless indicated in brackets)	Liner systems	2016		2015	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Arkil Inpipe GmbH	Berolina liner	33	100	100	↔
Arkil Inpipe GmbH	SAERTEX liner	15		100	↔
Hamers Leidingtechniek B.V.(**NL**)	Alphaliner	105		100	↔
Jeschke Umwelttechnik GmbH	Brandenburger liner	120		100	↔
Kanaltechnik Agricola GmbH	iMPREG liner	37		100	↔
KTF GmbH	iMPREG liner	94		99.0	↑
Max Bögl Stiftung & Co. KG	Brandenburger liner	46		-	-
Swietelsky-Faber Kanalsanierung GmbH (**D**)	Berolina liner	20		-	-
GMB Rioleringstechnieken B.V. (**NL**)	SAERTEX liner	134	99.3	-	-
Umwelttechnik und Wasserbau GmbH	Alphaliner	145	98.6	96.9	↑
Insituform Rioolrenovatietechnieken B.V. (**NL**)	Insituform CIPP liner (NL)	136	98.5	87.3	↑
ISS Kanal Services AG (**CH**)	Alphaliner	40	97.5	97.5	↔
Aarsleff Rohrsanierung GmbH	PAA SF liner	32	96.9	93.8	↑
Renotec N.V. (**B**)	SAERTEX liner	29	96.6	-	-
Average			**96.2**	**95.4**	↑
Aarsleff Rohrsanierung GmbH	iMPREG liner	46	93.5	75.0	↑
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	31	93.5	100	↓
TKT GmbH &Co.KG	Alphaliner	60	91.7	90.3	↑
Trasko a.s. (**CZ**)	Alphaliner	72	87.5	88.9	↓
Swietelsky-Faber Nederland Relining B.V. (**NL**)	iMPREG liner	47	80.9	-	-
Kumpen N.V. (**B**)	Brandenburger liner	56	76.8	-	-
Braumann Tiefbau GmbH (**A**)	Berolina liner	0	**	-	-
Geiger Kanaltechnik GmbH & Co.KG	Brandenburger liner	5	**	-	-
RTi Germany GmbH	SAERTEX liner	4	**	-	-
Swietelsky-Faber Kanalsanierung GmbH (**A**)	Brandenburger liner	0	**	-	-

* Target values in acc. with client's data (structural-analysis/sample data record)
** Too few/no samples with statement of the target data for combined thickness
– Not evaluated, too few liner samples

0.8%P, compared to the previous year. Seven companies passed all tests 100%. Among the four test criteria, the range of scores between the best and the poorest performing contractor is widest for wall thickness at 23.2%P (see Table 4).

Liners are watertight

The average for the water-tightness test criterion in 2016 was 99.1% (+0.5%P on 2015) and is thus closely approaching the 100% mark. Fourteen of the contractors examined succeeded in achieving this maximum and passing the test 100% with all their liner samples. Only three companies performed less well than in the previous year. Overall, the 2016 test results demonstrate that CIPP liners are watertight (see Table 5).

Rehabilitation quality in 2016

Individually, the test results for the four main criteria of modulus of elasticity, flexural strength, wall thickness and water-tightness each achieved a high level in 2016, both on an analysis by individual rehabilitation contractor and by liner system (see Table 6).

There are, it is true, some slightly poorer results compared to the previous year, but the long-term trend toward better rehabilitation quality recorded year-by-year since the first IKT LinerReport 2003/2004 continued in 2016.

The "100% Club"

In the past five years, in particular, it has become apparent that a number of rehabilitation contractors achieve optimum performance. These companies meet all four test criteria with all their liner samples and thus constitute what we are calling the "100% Club". Therefore, they are entirely fulfilling the requirements of the German "ZTV Material Test" (Supplementary Technical Contractual Conditions) and the expectations of their customers. Only five of the twenty-two companies are included in this Club in 2016 (in 2015 it was 9 of 24) and only few contractors maintain such high performance over several years.

Five contractors at the top

The 2016 results for the individual test criteria do exhibit high average success rates, but the overall quality of a liner is satisfactory only if it passes all four test criteria. The five companies that achieved this in 2016 and the liner systems they used were:

- Arkil Inpipe (D), using the Berolina liner
- Hamers Leidingtechniek (NL), using the Alphaliner
- Jeschke Umwelttechnik (D), using the Brandenburger liner
- Kanaltechnik Agricola (D), using the iMPREG liner
- KTF Kanal-Technik-Friess (D), using the iMPREG liner

In our new graphic (see page 8), every year in which a company has achieved membership of the "100% Club" is indicated by a

Table 5: Test results for water-tightness, 2016

Contractors and countries (Germany unless indicated in brackets)	Liner systems	2016		2015	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Arkil Inpipe GmbH	Berolina liner	41		100	↔
Arkil Inpipe GmbH	SAERTEX liner	82		96.9	↑
Braumann Tiefbau GmbH (**A**)	Berolina liner	28		-	-
Geiger Kanaltechnik GmbH & Co.KG	Brandenburger liner	29		-	-
Hamers Leidingtechniek B.V.(**NL**)	Alphaliner	105		100	↔
Insituform Rioolrenovatietechnieken B.V. (**NL**)	Insituform CIPP liner (NL) *	131		100	↔
ISS Kanal Services AG (**CH**)	Alphaliner	41		100	↑
Jeschke Umwelttechnik GmbH	Brandenburger liner	120	100	100	↔
Kanaltechnik Agricola GmbH	iMPREG liner	37		100	↔
KTF GmbH	iMPREG liner	88		100	↔
Kumpen N.V. (**B**)	Brandenburger liner	11		-	-
Max Bögl Stiftung & Co. KG	Brandenburger liner	46		-	-
RTi Germany GmbH	SAERTEX liner	47		-	-
Swietelsky-Faber Nederland Relining B.V. (**NL**)	iMPREG liner	47		-	-
Trasko a.s. (**CZ**)	Alphaliner	72		100	↔
TKT GmbH &Co.KG	Alphaliner	168	99.4	96.8	↑
Umwelttechnik und Wasserbau GmbH	Alphaliner	172	99.4	99.4	↔
Average			**99.1**	**98.6**	↑
Aarsleff Rohrsanierung GmbH	PAA SF liner *	84	98.8	99.1	↓
GMB Rioleringstechnieken B.V. (**NL**)	SAERTEX liner	124	98.4	-	-
Swietelsky-Faber Kanalsanierung GmbH (**D**)	Berolina liner	38	97.4	-	-
Swietelsky-Faber Kanalsanierung GmbH (**A**)	Brandenburger liner	30	96.7	100	↓
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	52	96.2	95.3	↑
Aarsleff Rohrsanierung GmbH	iMPREG liner	118	94.9	96.6	↓
Renotec N.V. (**B**)	SAERTEX liner	**	-	-	-

* No cutting of integrated inner film
** Test not commissioned
– Not evaluated, too few liner samples

Spot on! - 100% quality

Table 6: Test results by liner types, 2016

Liner system	Base material	Water-tightness		Modulus of elasticity		Flexural strength		Wall thickness	
		No. of samples	Watertight in % of tests	No. of samples	Target* achieved in % of tests	No. of samples	Target* achieved in % of tests	No. of samples	Target* achieved in % of tests
Berolina liner	GRP	107	99.1	107	100	107	100	53	100
Brandenburger liner	GRP	236	99.6	288	99.0	288	99.7	222	94.1
Alphaliner	GRP	610	99.3	618	99.4	618	98.5	453	95.8
Insituform CIPP liner (NL)	NF	131	100**	147	96.6	147	98.0	136	98.5
iMPREG liner	GRP	290	97.9	296	100	296	99.0	224	94.6
SAERTEX liner	GRP	253	99.2	295	98.3	295	95.9	178	98.9
PAA SF liner	NF	84	98.8**	92	96.7	92	97.8	32	96.9
Average			**99.1**		**98.9**		**98.4**		**96.2**

average or above average
below average
* Target values in accordance with client's data (structural-analysis/sample data record)
** Without cutting of integrated inner film
GRP: Glass-fibre-reinforced plastic base material
NF: Needle-felt backing material

Table 7: Test results compared to previous year

Liner type	Water-tightness watertight in % of tests			Modulus of elasticity Target* achieved in % of tests			Flexural strength Target* achieved in % of tests			Wall thickness Target* achieved in % of tests		
Averages	2016	2015	+/–	2016	2015	+/–	2016	2015	+/–	2016	2015	+/–
– All samples	99.1	98.6	+ 0.5 ↑	98.9	99.1	- 0.2 ↓	98.4	99.3	- 0.9 ↓	96.2	95.4	+ 0.8 ↑
– GRP	99.1	98.5	+ 0.6 ↑	99.3	99.3	0.0 ↔	98.4	99.5	- 1.1 ↓	95.9	96.2	- 0.3 ↓
– NF	99.5	99.5	+ 0.0 ↔	96.7	97.3	- 0.6 ↓	97.9	97.3	+ 0.6 ↑	98.2	89.8	+ 8.4 ↑

GRP: Glass-fibre-reinforced plastic backing material
NF: Needle-felt backing material
* Target values in acc. with client's data (structural analysis/sample data record)

star. The more stars a company has, the more consistently it has achieved top-quality rehabilitation results.

Eleven companies have performed totally satisfactorily in at least one year between 2012 and 2016.

Only one company has succeeded in achieving 100% for all four criteria throughout the five-year period. In our graphic, the five stars in a row underline this exceptional performance.

Long-term trend: rising quality

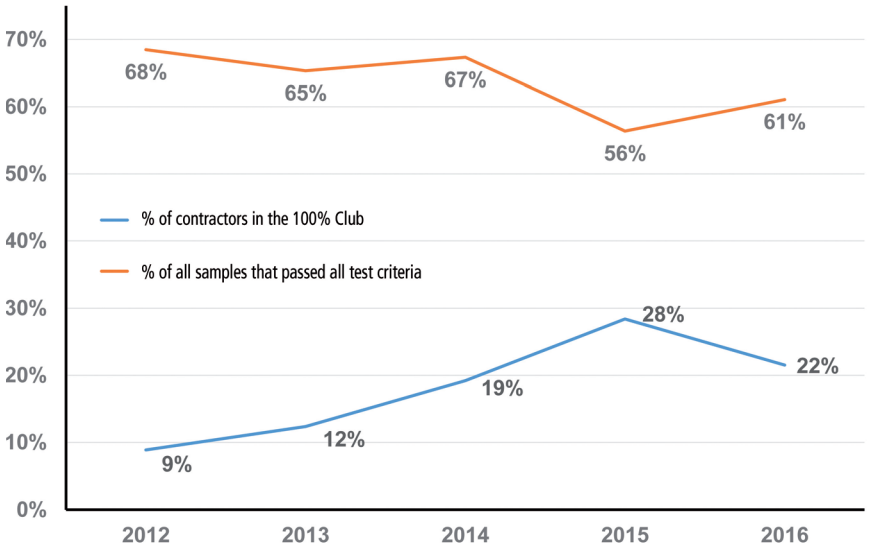
The overall trend is pleasing: in 2012, around 68% of all liner samples tested met all four test criteria simultaneously (with 9% of contractors in the "100% Club"). This figure remained virtually constant at around two-thirds in the subsequent two years (with 12% and 19% respectively of contractors in the "100% Club"). However, in 2015 the number of samples meeting all four criteria dropped to 56%, but there 28% of contractors were in the "100% Club". In 2016 the success rate has recovered to 61% although membership of the "100% Club" has dropped to 22% (see Diagram 1).

Conclusions

Three conclusions can be drawn from the data presented here for the 2016 IKT LinerReport:

- Firstly, the quality of CIPP liners has improved significantly in recent years. Around 60% of all site samples submitted meet all four test criteria completely satisfactorily. This, conversely, also means that this has

Diagram 1: Percentage of contractors who achieved 100% in all samples across all four test criteria each year



not been achieved in 40% of all cases.

- Secondly, only few rehabilitation contractors manage to maintain the "100% passed" level consistently over several years. For most contractors, meeting customers' requirements in all of their samples, i.e. 100%, is obviously an extremely demanding target. Quality fluctuates from year to year.
- Thirdly, the slight downturn in quality also means that the trend is not necessarily always upward. It can dip downward again, and an upward trend is therefore not a matter of course.

The liner manufacturers and the rehabilitation contractors need to assign importance in the coming years to achieving even better, and constantly high, quality. The aim must be that all liners, and not just around three fifths as in 2016, meet the quality criteria 100%.

However, there is also an obligation on the majority of municipal clients and water companies: they must insist on quality from the contractors, and must consistently have samples from each CIPP liner site tested.

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