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IKT - Institute for Underground Infrastructure

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The world of sewage systems

» The world of sewage systems is an exciting sector: how can lateral connections be rehabilitated reliably, how can manhole sealing be ensured on a long-term basis, how can the stability of largesection pipes be checked whilst in operation, how can rainwater treatment be decentralized, how can pressure sewer pipes be inspected and how can wastewater pipes be properly cleaned?

These are only some of the important topics that we have dealt with recently at IKT on behalf of sewer network operators. They are vital, both for improving standard operational procedures and for making decisions about capital investment. Therefore, they are topics which we, as an institute that works with an association of more than 130 network operators, are eager to deal with and apply in projects.

It is always our objective to create market transparency for network operators on the basis of scientific, neutral and independent project results. This must address their needs and the realities confronted on construction sites. For these reasons, IKT projects always include a communal steering committee who have a say in how they are conducted and are involved in decision making. In this way, we ensure our research projects and comparative product tests are practically oriented and our results are relevant to real situations.

Our project results can only be effectively implemented if as many specialists as possible are involved. So, we are glad to pass our findings on through numerous practical seminars, workshops and congresses, on the Internet, and through social media.

Therefore, we invite you to visit us, speak with us and bring us your suggestions and questions. If you wish, you can also do this virtually on our homepage, on Facebook or on LinkedIn. However, best of all – come and meet us at the institute in Gelsenkirchen! «

Roland W. Waniek
Managing Director
IKT - Institute for Underground Infrastructure

Content

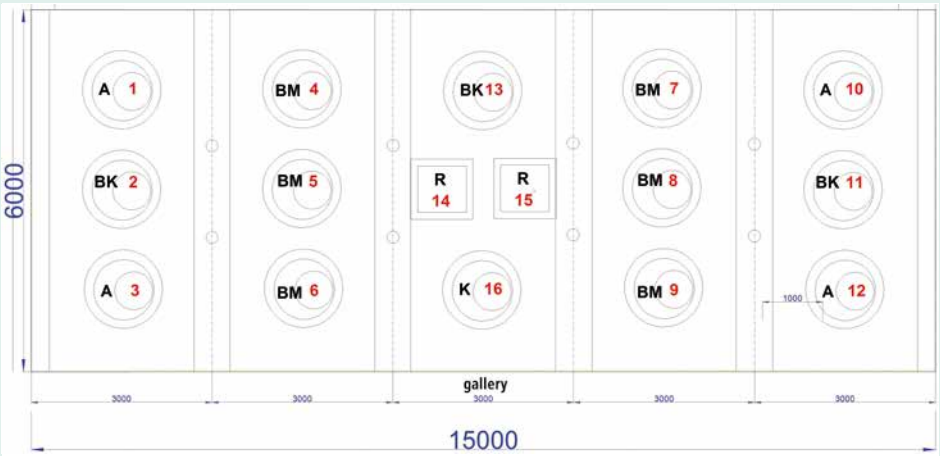
Coatings for a water-tight manhole shaft

IKT Comparative Test „Manhole Rehabilitation"

On-site installation conditions simulated in the large-scale test facility.

Can wastewater manholes be rehabilitated so that they remain permanently watertight? What are the benefits and the drawbacks of mortar coating, plastic coating and lining. What quality can be expected? This first comparative product test in this field gives you the answers!

Many manholes are leaky. The latest IKT Comparative Test provides selection criteria for the right rehabilitation method.



A = manhole with lining, BM = manhole with mortar coating, BK = manhole with plastic coating, K = plastic manhole, R = rectangle manhole for mortar coating, Red figure = manhole number

All according to plan: thirteen manholes set up for the Comparative Test and three for supplementary investigations

"Now for the manholes" – this is a train of thought in the repair/rehabilitation departments of many wastewater network operators. There is, indeed, little point in rehabilitating wastewater pipes without paying attention to the numerous defective manholes. This is particularly true in water infiltration zones, since a really watertight sewer network can only be achieved provided the manholes are also rehabilitated.

Under test: thirteen manhole-rehabilitation methods

But which of the many manhole rehabilitation methods should we choose? Which one will seal reliably and durably? Which is suitable in which situation, and which are not suitable? Thirteen commercially available methods have now been analysed in IKT's „Manhole Rehabilitation" Comparative Test. The results range from GOOD to ADEQUATE, with one method failing the test.

Joint state/municipal funding

The North Rhine-Westfalia environmental ministry and the municipalities on the steering committee jointly funded this IKT Comparative Test. Testing and documentation of the results was performed by IKT, an independent and impartial institute. IKT was responsible for the engineering science development of the test concept and for the implementation of the test programme. Relevant decisions were coordinated and agreed with the steering committee.

Rehabilitation task and test programme

The task set for the participants was to rehabilitate an approximately 5 m high DN 1000 concrete manhole in which defined defects had been

Installation of the manholes: conditions can be replicated on a 1:1 scale in the IKT large-scale test facility, which is unique in the world.

IKT Comparative Test

This project's wastewater network operator steering committee selected the following methods:

Table 1: Methods tested in the IKT "Manhole Rehabilitation" Comparative Test

Supplier	System
a) Mortar coatings	
Hermes Technologie GmbH & Co. KG	Ergelit KS 1
MC-Bauchemie Müller GmbH & Co. KG	Ombran MHP
PCI Augsburg GmbH	Nanocret R4
Remmers Baustofftechnik GmbH	Betofix R4 SR
Remmers Baustofftechnik GmbH	Silicate R
Sika Deutschland GmbH	Sewer reprofiling mortar
b) Plastic coatings	
FSB Bautechnik GmbH	Spectrashield
PSL Handels GmbH	Oldodur WS 56
Source One Environmental UK (S1E)	Ultracoat
c) Linings	
Aarsleff Rohrsanierung GmbH	GRP, back-anchored
Hobas Rohre GmbH	GRP inner shaft
SEKISUI SPR Germany GmbH	GRP, adhesive
Schacht + Trumme Sielregulierungen W. Schwarz GmbH	HDPE segmental lining

Area damage: nine drilled holes of 5 mm dia. in an area of 20 x 20 cm and application of mould release agent to a small area

Area damage: nine drilled holes of 5 mm dia. in an area of 20 x 20 cm, application of mould release agent to a large area

installed, against a rising groundwater table. The central elements of the test programme were testing of system performance and examination of the participant's quality assurance provisions. A total of thirteen manholes consisting

Test task: the participants had to repair a „pre-damaged" manhole.

of prefabricated concrete elements with a nominal diameter of DN 1000 were installed in IKT's large-scale test facility for the system tests.

The participating wastewater network operators selected the following damage scenarios in order to simulate as authentically as possible the condition of a damaged manhole and the actual challenges involved in rehabilitation:

- 8x „isolated damage": point damage in the form of a 10 mm dia. drill hole
- 4x „area damage": nine drilled holes of 5 mm dia. in a 20 cm x 20 cm area, with simulation of point defects in substrate preparation (mould release agent)

Isolated damage: every manhole was subjected to „pre-damage" in the form of eight drilled holes (dia.: 10 mm).

Five leaking ring joints per manhole: four drilled holes of 6 mm dia. per joint

- 5x „leaking ring joint": ring joint with four 6 mm dia. drill holes

The rehabilitation target was to restore the water-tightness and load-bearing capability of the manhole. How this was to be achieved was left up to each individual comparative test participant, i.e., each had sole responsibility for planning, conception, rehabilitation and finishing work. There was no time limit.

Test programme and assessment system

After completion of the manhole rehabilitation operations, performance against rising water level was first measured in accordance with DIN EN 1610. The focus during the system tests was on loads exerted by external water pressure:

- Short-term exposure to groundwater, in increments up to 5 m, holding time: 17.5 days (3.5 days per load level)
- Long-term exposure to groundwater, constant at 5 m, holding time: 67 days

The manholes were inspected after each increase in water level. They continued to be visually and acoustically inspected once per week when the maximum water level of 5 m had been rea-

ched. All leaks, cavities, cracks and other abnormalities were noted during these inspections.

After completion of the groundwater loading test, tensile adhesion strengths were measured and any leaking points on the access system documented. The non-destructive MAC method, which functions using a horizontal pressure and fine sensors, was also used to measure ring stiffness. For more information about MAC see page 33. These criteria were incorporated into the Comparative Test as additional information with no grading. Proofs of load-bearing capability and protective action, and aspects of quality assurance, were also investigated.

Infiltration water-tightness

The criterion of „infiltration water-tightness" was evaluated on the basis of observations made during the short-term and long-term groundwater exposure tests. Differentiation was made here between the following conditions:

- No abnormalities
- Damp patch ≤ 25 cm²
- Damp patch > 25 cm²
- Damp patch with spreading plume ≥ 40 cm
- Infiltration

Load bearing capability

The criterion of „load bearing capability" was evaluated for 5 m external water pressure. The systems used were grouped in terms of their functional mechanism. Whether they form an adhesive bond with the substrate (the „adhesive bond" case), whether they are back-anchored by means of special support elements or are completely self-supporting (the „back-anchored/self-supporting" case).

In the „adhesive bond" cases, „tensile adhesion strength", „hollow points", „cracks" and „blisters" were observed, and any abnormalities were evaluated and graded. Where hollow points occurred, these were included, referred to in the total area treated, as „zero values" in the averaging of the tensile adhesion tests.

In the „back-anchored/self-supporting" cases, there is no large-area adhesive bond with the substrate. A self-supporting action was then considered to be system behaviour if it could be substantiated by means of corresponding proof of structural-analysis. This criterion was graded as „deficient" if such proof could not be furnished.

Robustness

The „robustness" criterion relates solely to the „area damage" scenario. A mould release agent was applied to the target surfaces immediately prior to rehabilitation, in order to provide indications of the resistance of the rehabilitation system to unexpected bonding defects. These can occur in practice where there is a lack of substrate pre-treatment.

Differentiation was made between the rehabilitation systems according to their load-bearing behaviour for evaluation of the „robustness" criterion:

- Case 1: Adhesive bond with the substrate
- Case 2: Back-anchoring using special support elements
- Case 3: Pipe-in-pipe system

„Bonding with the surrounding material" (not relevant for Case 3), „deformations", „tensile strength deficiencies" and „infiltration" were recorded and abnormalities evaluated and graded for the „robustness" criterion.

Acceptability of completed work

An assessment of the acceptability of the completed work was undertaken by the assessment committee (a group of network operators from the steering committee) throught inspection

Abnormalities: members of the assessment committee discuss their observations.

directly in the manhole and by the entire steering committee, with award of grades, using camera-based video documentation material.

Steering committee

Every IKT Comparative Test is supported by a steering committee consisting of sewer network operators. The role of the committee is to:

- select the products to be tested;
- specify the test concept;
- define performance targets and quality requirements, and
- evaluate and grade the test results.

The steering committee for the „Manhole Rehabilitation" Comparative Test consisted of seventeen sewer network operators:

- The municipality of Arnhem (NL)
- Backnang municipal drainage department
- Burscheid municipal utilities
- City of Emsdetten wastewater treatment plant
- Essen municipal utilities
- City of Euskirchen
- Hagen municipal services
- City of Iserlohn
- Kempten municipal services
- Kiel municipal drainage department
- Cologne municipal drainage utilities
- Lünen municipal wastewater management services
- Minden municipal services
- Bad Oeynhausen municipal utilities
- Troisdorf wastewater management department
- Vogtland water/wastewater special-purpose municipal alliance
- City of Willich wastewater management department

Serdar Ulutaş, Dipl.-Ing. (FH), MBA, head of IKT Comparative Test reports to the steering committee on the current status of the project.

Protective action

Demonstrations of suitability of the systems for use in wastewater facilities within the permissible pH range were required from the suppliers. Such proof of "protective action" was considered to have been provided if a DIBt (German

Institute for Building Technology) approval or evidence analogous to the DIBt approval tests was submitted. Exposure tests on mortar and plastic in aggressive and in particularly aggressive fluids were then performed, in order to verify the protective action of the materials used on a random-sampling basis. Scores were uprated by one grade if no abnormalities were found.

Quality Assurance

The suppliers' quality assurance assessment covered criteria such as method description, training provisions, test certificates and third-party supervision. „Particular abnormalities" were recorded for any additional features of the performance of the work that were observed.

On-site tests

The on-site tests were undertaken to determine the practicability of the rehabilitation methods under real on-site conditions. These on-site tests provided a check of how representative the testing in the IKT test facilities was of real conditions. For this purpose, essential working operations were observed. In particular, the nature and scope of preparatory work were noted and deviations from the requirements in the method manuals and/or from the work performed at the IKT test facilities were recorded. In addition, the on-site tests were also used to record any „particular abnormalities" as part of the suppliers' quality assurance assessment.

Table 2 summarises the overall evaluation system, including additional information, and shows the weighting of these criteria that was specified by the network operators.

IKT Comparative Test „Manhole rehabilitation": Test results

The overall scores in the IKT Comparative Test, „Manhole rehabilitation" ranged from GOOD to ADEQUATE:

- GOOD (1.6): Hobas Rohre GmbH, using GRP inner manhole shaft
- GOOD (1.7): PCI Augsburg GmbH, using Nanocret R4
- GOOD (2.1): Schacht + Trumme GmbH, using HDPE segmental lining
- GOOD (2.1): Sika Deutschland GmbH, using sewer reprofiling mortar
- GOOD (2.2): Aarsleff Rohrsanierung GmbH, using GRP – back-anchored
- SATISFACTORY (2.6): PSL Handels GmbH, using Oldodur WS 56
- SATISFACTORY (2.7): Hermes Technologie GmbH, using Ergelit KS 1
- SATISFACTORY (2.8): Source One Environmental UK, using Ultracoat
- SATISFACTORY (2.9): Remmers Baustofftechnik GmbH, using Betofix R4 SR
- SATISFACTORY (3.5): SEKISUI SPR Germany GmbH, using GRP – adhesive
- SATISFACTORY (3.5): Remmers Baustofftechnik GmbH, using Silicate R
- ADEQUATE (3.6): MC-Bauchemie Müller GmbH, using Ombran MHP
- NOT EVALUABLE: FSB Bautechnik GmbH, using Spectrashield

Due to a system failure caused by the „predamage" areas (mould release agent applied to assess „robustness"), it was not possible to evaluate the „Spectrashield" system. It was no longer possible to enter the manhole.

System failure: It was not possible to evaluate the „Spectrashield" system.

Results for infiltration water-tightness

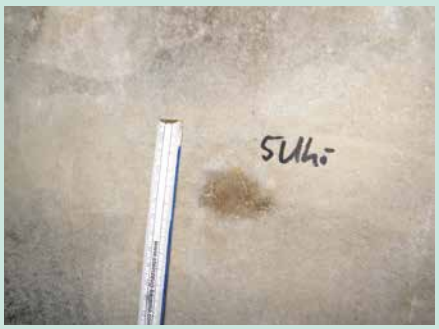
None of the methods exhibited any abnormalities after the short-term and long-term groundwater exposure resulting from the „isolated damage" scenarios. All of the 96 points of damage across the rehabilitated manholes were watertight (100 %). This damage scenario clearly presented no problem to the rehabilitation systems tested.

Abnormalities caused by the "leaking ring joint" became apparent during the short-term groundwater simulation at 5 m affecting 14 of the 60 repairs (approx. 23 %). During the subsequent long-term groundwater simulation at 5 m, three of these exhibited a change in their condition and new abnormalities (damp patches) were

Table 2: Evaluation system, showing weighting of the criteria

Evaluation system	
System performance (85 %)	**Participant's quality assurance (15 %)**
Infiltration-water tightness (40 %)	Method description (20 %): • Method manual (10 %) • Technical note sheets (10 %)
Load-bearing capability (20 %)	Training provisions (20 %): • Training of rehabilitator (10 %) • Manufacturer's training courses (10 %)
Robustness (20 %)	Test certificates (20 %)
Acceptability of completed work (15 %)	Third-party supervision (20 %)
Protective action (5 %)	Particular abnormalities – System tests, on-site tests (20 %)
Addition information (with no grading) • Leaks at access system • Filling-level measurement after rehabilitation • Auxiliary supporting action and MAC stiffness	

recorded at three more points, bringing the total to 17 of the 60 repairs. So at the end of the experiment there were no abnormalities recorded for 43 points of damage (around 72 %).



Damp patch smaller than 25 cm

Damp patch larger than 25 cm

Damp patch with spreading plume

Infiltration

Where a point of damage had been suitably repaired and exhibited no abnormalities at the start of the groundwater exposure testing, it generally remained in this condition throughout (139 of 156 points of damage, approx. 89 %). No additional infiltration (long-term groundwater simulation at 5.0 m) was exhibited at 154 points of damage (approx. 99 %) up to the end of the test.

Deficiencies in substrate preparation: blisters and cracks may be the result if the mould release agent prevents secure bonding.

Load-bearing capability: adhesive bond with substrate

In the case of the „isolated damage" scenario, repairs to 216 of the 240 points of damage (approx. 90 %) exhibited no abnormalities. With one exception, this damage scenario thus presented no significant problem for the rehabilitation systems tested.

In the case of the „leaking ring joint" damage scenario, 133 of 150 load-bearing evaluations (approx. 89 %) exhibited no abnormality. The „Ombran MHP" system exhibited two slight tensile strength deficiencies, which did not result in loss of score. Therefore, this damage scenario also presented no significant problem to the rehabilitation systems tested.

Cracks are indicative of an inadequate adhesive bond with the substrate.

No abnormalities were exhibited by 7 of 10 systems (70 %) in the „remaining manhole wall" sector. The „Ombran MHP" and „Ergelit KS 1" mortar systems exhibited extensive hollow points. In addition, tensile strength deficiencies (cracks), which resulted in minus points, were apparent in the case of the „Ergelit KS 1" system.

Among the 13 systems, only the „Spectrashield" exhibited abnormalities for mean tensile adhesion strength.

A grade of 1.0 was awarded to 7 of 10 suppliers for „load-bearing capability". Three systems („Ombran MHP", „Ergelit KS 1" and „Spectrashield") each scored of 5.0.

Load-bearing capability: Back-anchored/ self-supporting

A structural-analysis certificate was submitted for only one of the three back-anchored/self-supporting systems („GRP inner shaft"). The load-bearing capability of the „ GRP – Back-anchored" and „HDPE - Segmental lining" remains unknown.

Immunity („robustness") to punctual deficiencies in substrate preparation

No abnormalities were apparent at 44 of the 52 (approx. 85 %) points for the „inadequate bonding with the surrounding material" points of damage. Two mortar coatings exhibited abnormalities in the form of hollow point enlargements („Ombran MHP" 1 of 4 and „Silicate R" 2 of 4 damage locations). Two plastic coatings („Spectrashield" and „Oldodur WS 56") exhibited abnormalities at five of eight points of damage. No abnormalities were found on the four remaining lining systems and four mortar systems, or on the epoxy-resin plastic coating.

No abnormalities for „excessive deformation" were observed for 46 of 52 points of damage (approx. 89 %). For two plastic coatings („Spectrashield" and „Oldodur WS 56"), abnormalities in the form of blisters were observed at six of the eight points of damage. The six mortar

Cracking in a zone pre-treated with mould release agent.

coatings, the four lining systems and the epoxy-resin plastic coating („Ultracoat") exhibited no abnormalities.

For „tensile strength deficiency", 41 of the 48 points of damage (approx. 85 %) had no abnormalities. Three mortar coatings exhibited cracks. The four lining systems, three mortar systems and two plastic coatings had no abnormalities.

For „infiltration", there were no abnormalities at 33 of 48 points of damage (approx. 69 %). Damp patches and/or spreading plumes were found on all six mortar coatings. One plastic coating („Oldodur WS 56") exhibited infiltrating water at one of four points of damage. No abnormalities were noted on the four lining systems and on the epoxy-resin plastic coating.

Where inadequate bonding had been ascertained in the vicinity of „area damage", leaks generally also occurred at these locations. Leaks were also exhibited in all cases where cracks occurred in a mortar coating. No abnormalities were found in the four lining systems and in the epoxy-resin plastic coating.

The IKT Comparative Test concept

Products and methods are tested in detail under laboratory and under practical conditions in comparative product tests. Sewer network operators are provided with substantiated information on the strengths and weaknesses of commercially available products, enabling them to base their purchasing decisions on hard facts, and not just on the manufacturers' advertising. IKT Comparative Tests also provide manufacturers with information needed for improving their products, so they can achieve better market ranking. Ultimately, the entire industry benefits.

Acceptability of repair

The overall grades awarded for the acceptability of repair ranged from Very Good (1.1) to Adequate (3.7). Three systems were Very Good, five were Good, three were Satisfactory and one was graded Adequate (average overall grade: 2.2). Significant differences in grades were found between the individual systems.


Acceptability of repair: the assessment committee subjected all the manholes to extremely precise inspection.

Protective action

Evidence for verification of protective action was provided for four of thirteen systems. A DIBt approval exists for three systems („Ombran MHP", „Ergelit KS 1" and „Spectrashield"). An analysis certificate, as necessary for DIBt approval, was submitted for the „Silicate R" system. None of the systems exhibited any abnormalities in random-sampling tests. All systems therefore had their scores increased by one grade.

Quality assurance by the system suppliers and/or refurbishing contractors was extremely patchy. Results are compiled in the test tables.

Conclusions

Reliable manhole rehabilitation possible using commercially available systems

The systems tested in the IKT Comparative Test demonstrated that reliable manhole rehabilitation is possible even when exposed to groundwater pressure. However, the range of scores awarded to the individual systems is wide, extending from GOOD to ADEQUATE.

System failure due to substrate-preparation deficiencies in individual cases

One of the coating systems could not be evaluated, since it proved to be extremely sensitive to isolated deficiencies in substrate preparation (test criterion „robustness"). Giant bubbles, which prevented renewed entry to the manhole, developed under exposure to external water pressure, starting from the local weak points where mould release agent had been applied for the test. Other systems exhibited cracking, blistering, hollow point enlargements and leaks at such points.

Water-tightness performance recognisable at early stage if groundwater present

Where the refurbished manholes were watertight immediately after initial exposure to groundwater, no further deterioration in quality was generally observed, even under greater and more prolonged exposure to groundwater. Therefore acceptance inspection is recommended when groundwater is present on-site.

Load-bearing capability critical or unknown in some systems

Analyses of the load-bearing capability of the various systems produced greatly differing results. Some systems based on adhesive bonding exhibited extensive cavity areas and cracking, and received the „Deficient" grade, whereas others convincingly achieved „Very Good". A structural-analysis certificate was available only in one case for the two self-supporting linings and one system incorporating back-anchoring using support elements, while the load-bearing capability of the two other systems still remains unknown.

Protective action not clarified in a large number of systems

Only four of thirteen suppliers were able to submit certificates for the use of their materials/systems in wastewater facilities. No abnormalities were found in random-sampling tests (exposure tests), however.

Quality assurance very patchy

The majority of system suppliers and rehabilitation contractors were able to cite training certificates, test certificates, DIBt approvals, etc., only in individual cases. Overall large gaps were apparent.

MAC measurement confirms auxiliary supporting action

The MAC measurements showed that all coatings, and linings with full-area contact/bonding

The MAC method made it possible to determine the ring stiffness of the refurbished manhole by non-destructive means.

with the original manhole walls, are capable of making a significant contribution to the restoration of horizontal ring stiffness. In many cases, the data for an intact system were again achieved - or even exceeded - even in the case of cracked manhole-shaft rings.

Acceptance impression of system operators confirms test results

The evaluation of the work performed, undertaken by the representatives of the wastewater network operators – the „acceptance impression" - largely coincided with the results of the extensive tests performed for the IKT Comparative Test. However, this presupposes extensive experience on the part of the individual employees.

The Authors

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Photos of the presentation of results at IKT

Dipl.-Ök. Roland W. Waniek, director, welcomes the guests to the presentation of results of the IKT „Manhole rehabilitation" Comparative Test.

Critical questions from the audience are always welcome.

Dipl.-Ing. (FH) Serdar Ulutaş, MBA, head of IKT Comparative Test, presents the results of this Comparative Test.

Dipl.-Ing. Frank W. Grauvogel, of the Burscheid municipal technical services, presents the steering committee's viewpoint.

Guests await the results of the latest IKT Comparative Test.

The summary report contains all the essential information (download German versions: www.ikt.de/downloads/warentest-berichte/).

Prof. Dr.-Ing. habil. Bert Bosseler, Scientific Head of the IKT, answers guests' questions.

Lively discussion continues after presentation of the results.

IKT Comparative Test "Manhole Rehabilitation"

Task: Rehabilitation of an approximately 5 m high DN 1000 concrete manhole in which defined defects had been installed, against a rising groundwater table.

- 8x "isolated damage": point damage in the form of a 10 mm dia. drill hole.
- 4x "area damage": nine drilled holes of 5 mm dia. in a 20 cm x 20 cm area, with simulation of point defects in substrate preparation (mould release agent)
- 5x "leaking ring joint": ring joint with four 6 mm dia. drill holes

Contractor	**Hobas Rohre GmbH**	**PCI Augsburg GmbH**	**Schacht + TrummeSielregulierungen W. Schwarz GmbH**	**Sika Deutschland GmbH**	**Aarsleff Rohrsanierung GmbH**	**PSL Handels GmbH**	**Hermes Technologie GmbH & Co. KG**
Systems	GRP inner manhole shaft	Nanocret R4	PE-HD segmental lining	Sewer reprofiling mortar	GRP, back-anchored	Oldodur WS 56	Ergelit KS1
installed by	Aarsleff Rohrsanierung GmbH[5]	Aarsleff Rohrsanierung GmbH[6]	Schacht + Trumme Sielregulierungen W. Schwarz GmbH	Peter Presch - Kunststoffverarbeitung GmbH	Aarsleff Rohrsanierung GmbH	Schulz Bau GmbH	DiTom Kanaltechnik GmbH
IKT test results*	**GOOD (1.6)**	**GOOD (1.7)**	**GOOD (2.1)**	**GOOD (2.1)**	**GOOD (2.2)**	**SATISFACTORY (2.6)**	**SATISFACTORY(2.7)**
System tests (85 %)	**Very Good (1.2)**	**Very Good (1.3)**	**Good (2.0)**	**Very Good (1.5)**	**Good (2.1)**	**Good (2.3)**	**Good (2.5)**
Infiltration water tightness (40 %)	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.2**
• Short-term exposure to groundwater, in increments up to 5 m, holding time: 17.5 days (3.5 days per load level) (20 %)	1.0	1.0	1.0	1.0	1.0	1.0	1.2
• Long-term exposure to groundwater, constant at 5 m, holding time: 67 days (20 %)	1.0	1.0	1.0	1.0	1.0	1.0	1.2
Load-bearing capability (20 %)	**1.0**	**1.0**	**5.0**	**1.0**	**5.0**	**1.0**	**5.0**
Robustness[1] (20 %) to point defects in substrate preparation	**1.0**	**1.3**	**1.0**	**2.0**	**1.0**	**6.0**	**2.0**
Acceptability of completed work [2] (15 %)	**1.2**	**1.4**	**1.1**	**1.9**	**1.7**	**1.8**	**3.3**
Protective action[3] (5 %)	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**2.0**
Quality Assurance[4] (15 %)	**Satisfactory (3.5)**	**Adequate (4.0)**	**Good (2.5)**	**Deficient (5.5)**	**Satisfactory (3.0)**	**Adequate (4.5)**	**Adequate (4.0)**
Method description (20 %): Method description (10 %), Technical note sheets (10 %)	+ +	+ +	+ +	- +	+ +	+ +	+ +
Training provisions (20 %): Training of rehabilitator (10 %), Manufacturer's training courses (10 %)	- -	- -	+ -	- -	+ -	+ -	- -
Test certificates (20 %)	o	-	-	-	o	-	+
Third-party supervision (20 %)	+	+	+	-	+	-	-
"Particular abnormalities" (20 %)	in situ: mixing of grout and waste water[5] (-)	in situ: mixing of mortar by eye (-)	no abnormalities(+)	in situ: no bid (-)	in situ: rehabilitation declined (-)	in situ: Drying of reprofiling mortar using hot-air blower (-)	System test and in situ: Mixing of mortar by eye (-)
Addition information (with no grading):							
Static system MAC stiffness (intact system = 100 %)[8]	self-supporting after rehabilitation> 150 %	adhesive bond after rehabilitation> 150 %	self-supporting after rehabilitation > 150 %	adhesive bond after rehabilitation> 150 %	support elements after rehabilitation no **contribution to stiffness**	adhesive bond after rehabilitation 100 - 150 %	adhesive bond after rehabilitation> 150 %
Leaking points on the access system	0 of 10 climbing iron connections	0 of 18 access systems	0 of 32 climbing iron connections	2 of 18 access systems	17 of 18 access systems	0 of 18 access systems	1 of 18 access systems
Surface preparation: Implementation and time required (approx.)	no surface preparation	manual high-pressure-water-jetting at 400 bar, 1 Std.	no surface preparation	manual abrasive jetting at 8 bar, 1 Std.	no surface preparation	manual high pressure-water-jetting at 310 bar, 1 Std.	mechanical high-pressure-water jetting with granulate and 385 bar, 1 h
Rehabilitation: Implementation and time required (approx.)	manual, segment-by-segment, 6 h	hand-held trowel, 5 h	manual, segment-by-segment, 9 h	hand-held trowel, 8 h	manual, 15 h	hand-held spray gun, 1 h	hand-held trowel, 3 Std.
Total working hours (approx.) / days on site	12 h. / 2 d	10 h. / 2 d	15 h / 3 d	14 h / 2 d	27 h / 2 d	5 h / 2 d	12 h / 2 d
Filling-level test after rehabilitation	passed	passed	passed	passed	passed	passed	passed
Costs, not including VAT	8,950 EUR	2,870 EUR	6,250 EUR	5,270 EUR	6,410 EUR	7,350 EUR	2,820 EUR

* Note calculation based on non-rounded values
** System failure after 8 days of short-term exposure to groundwater: formation of two bubbles, no entry to the manhole possible. Inspection, testing and evaluation cancelled.

1 Robustness to point defects in substrate preparation: simulation of inadequate pre-treatment, as can occur in practice.
2 Impression made at on-site acceptance inspection: entry to manhole and video evaluation by members of the steering committee.
3 Protective action against aggressive environmental conditions: is considered demonstrated provided the relevant documents can be submitted, e.g. DIBt approval. Grades awarded on the basis of pH class and, where appropriate, passing of random-sampling test.
4 Evaluation: "+" = demonstrated; "-" = not demonstrated; "o" = partially demonstrated.
5 The in-situ work was performed by Sanierungstechnik Dommel GmbH, since Aarsleff Rohrsanierung GmbH declined to perform rehabilitation.
6 The in-situ work was performed by Schulz Bau GmbH, since Aarsleff Rohrsanierung GmbH declined to perform rehabilitation.
7 "System failure" signifies that there is an immediate need for rehabilitation because, for example, entry to the manhole is no longer possible and/or the hydraulic properties of the manhole have been severely impaired.
8 Notes on the supplementary load-bearing action of the systems: here, the increase in overall stiffness is measured against the initial stiffness of the intact manhole shaft using the MAC system (http://www.ikt.de/pruefstelle/standsicherheit-von-grossprofilen) after rehabilitation.

Evaluation key for test results: Very Good = 1.0 - 1.5. Good = 1.6 - 2.5. Satisfactory = 2.6 - 3.5. Adequate = 3.6 - 4.5. Deficient = 4.6 - 5.5. Inadequate = 5.6 - 6.0

IKT Comparative Test "Manhole Rehabilitation"

Task: Rehabilitation of an approximately 5 m high DN 1000 concrete manhole in which defined defects had been installed, against a rising groundwater table.

- 8x "isolated damage": point damage in the form of a 10 mm dia. drill hole.
- 4x "area damage": nine drilled holes of 5 mm dia. in a 20 cm x 20 cm area, with simulation of point defects in substrate preparation (mould release agent)
- 5x "leaking ring joint": ring joint with four 6 mm dia. drill holes

Contractor	**Source One Environmental UK (S1E)**	**Remmers Baustofftechnik GmbH**	**SEKISUI SPR Germany GmbH**	**Remmers Baustofftechnik GmbH**	**MC-Bauchemie Müller GmbH & Co. KG**	**FSB Bautechnik GmbH**
Systems	Ultracoat	Betofix R4 SR	GRP / Adhesive	Silicate R	Ombran MHP	Spectrashield
installed by	Source One Environmental UK (S1E)	SMG Bautenschutztechnik für Hoch- und Tiefbau GmbH	KMG Pipe Technologies GmbH	SMG Bautenschutztechnik für Hoch- und Tiefbau GmbH	Heikaus KS Kanalsanierungen GmbH	BSG Beschichtungs GmbH
IKT test results *	**SATISFACTORY (2.8)**	**SATISFACTORY (2.9)**	**SATISFACTORY (3.5)**	**SATISFACTORY (3.5)**	**SUFFICIENT (3.6)**	**NOT EVALUABLE** due to a system failure**
System tests (85 %)	**Good (2.5)**	**Satisfactory (2.8)**	**Satisfactory (3.0)**	**Satisfactory (3.6)**	**Adequate (4.0)**	**Not evaluable**
Infiltration water tightness (40 %)	**3.8**	**1.8**	**4.5**	**4.5**	**3.1**	**Not evaluable**
• Short-term exposure to groundwater, in increments up to 5 m. holding time: 17.5 days (3.5 days per load level) (20 %)	3.8	1.7	4.5	4.5	2.6	Not evaluable
• Long-term exposure to groundwater, constant at 5 m. holding time: 67 days (20 %)	3.8	1.9	4.5	4.5	3.3	Not evaluable
Load-bearing capability (20 %)	**1.0**	**1.0**	**1.0**	**1.0**	**5.0**	**5.0**
Robustness[1] (20 %) to point defects in substrate preparation	**1.0**	**6.0**	**1.0**	**6.0**	**6.0**	**6.0[7]**
Acceptability of completed work [2] (15 %)	**2.2**	**2.5**	**3.7**	**2.6**	**3.2**	**Not evaluable**
Protective action[3] (5 %)	**5.0**	**5.0**	**5.0**	**1.0**	**2.0**	**1.0**
Quality Assurance[4] (15 %)	**Adequate (4.5)**	**Satisfactory (3.5)**	**Inadequate (6.0)**	**Satisfactory (3.0)**	**Very Good (1.0)**	**Good (2.5)**
Method description (20 %): Method description (10 %). Technical note sheets (10 %)	- +	- +	- -	- +	+ +	+ +
Training provisions (20 %): Training of rehabilitator (10 %). Manufacturer's training courses (10 %)	- -	- -	- -	+ -	+ +	+ -
Test certificates (20 %)	+	-	-	-	+	+
Third-party supervision (20 %)	-	+	-	+	+	-
"Particular abnormalities" (20 %)	in situ: Drying of reprofiling mortar using hot-air blower (-)	no abnormalities (+)	Quality Assurance: no reaction on inquires and requests (-)	no abnormalities (+)	no abnormalities (+)	no abnormalities (+)
Addition information (with no grading):						
Static system MAC stiffness (intact system = 100 %)[8]	adhesive bond after rehabilitation 100 - 150 %	adhesive bond after rehabilitation> 150 %	adhesive bond after rehabilitation 100 - 150 %	adhesive bond after rehabilitation> 150 %	adhesive bond after rehabilitation> 150 %	adhesive bond after rehabilitation 100 - 150 %
Leaking points on the access system	1 of 18 access systems	3 of 18 access systems	2 of 18 access systems	0 of 18 access systems	1 of 18 access systems	not evaluable
Surface preparation: Implementation and time required (approx.)	manual high-pressure-water-jetting with 250 bar. 1 h	manual high-pressure-water jetting (unknown pressure). 1 h	no surface preparation	mechanical high-pressure-water jetting with granulate (unknown pressure). 2 h	mechanical high-pressure-water jetting with granulate and 500 bar. 1 h	manual high-pressure-water-jetting with 500 bar. 1 h
Rehabilitation: Implementation and time required (approx.)	hand-held spray gun. 1 Std.	hand-held trowel. 2 Std.	hand-held (mat-by-mat). 15 Std.	hand-held. 2 Std.	hand-held trowel. 4 Std.	hand-held spray gun. 2 Std.
Total working hours (approx.) / days on site	10 h / 3 d	7 h / 2 d	20 h / 2 d	7 h / 2 d	10 h / 2 d	9 h / 1 d
Filling-level test after Rehabilitation	passed	passed	not passed	not passed	passed	passed
Costs, not including VAT	5,040 EUR	1,940 EUR	3,770 EUR	2,240 EUR	5,500 EUR	3,870 EUR

* Note calculation is based on non-rounded values
** System failure after 8 days of short-term exposure to groundwater: formation of two bubbles. no entry to the manhole possible. Inspection, testing and evaluation cancelled.

1 Robustness to point defects in substrate preparation: simulation of inadequate pre-treatment, as can occur in practice.
2 Impression made at on-site acceptance inspection: entry to manhole and video evaluation by members of the steering committee.
3 Protective action against aggressive environmental conditions: is considered demonstrated provided the relevant documents can be submitted, e.g. DIBt approval. Grades awarded on the basis of pH class and, where appropriate, passing of random-sampling test.
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7 "System failure" signifies that there is an immediate need for rehabilitation because, for example, entry to the manhole is no longer possible and/or the hydraulic properties of the manhole have been severely impaired.
8 Notes on the supplementary load-bearing action of the systems: here, the increase in overall stiffness is measured against the initial stiffness of the intact manhole shaft using the MAC system (http://www.ikt.de/pruefstelle/standsicherheit-von-grossprofilen) after rehabilitation.

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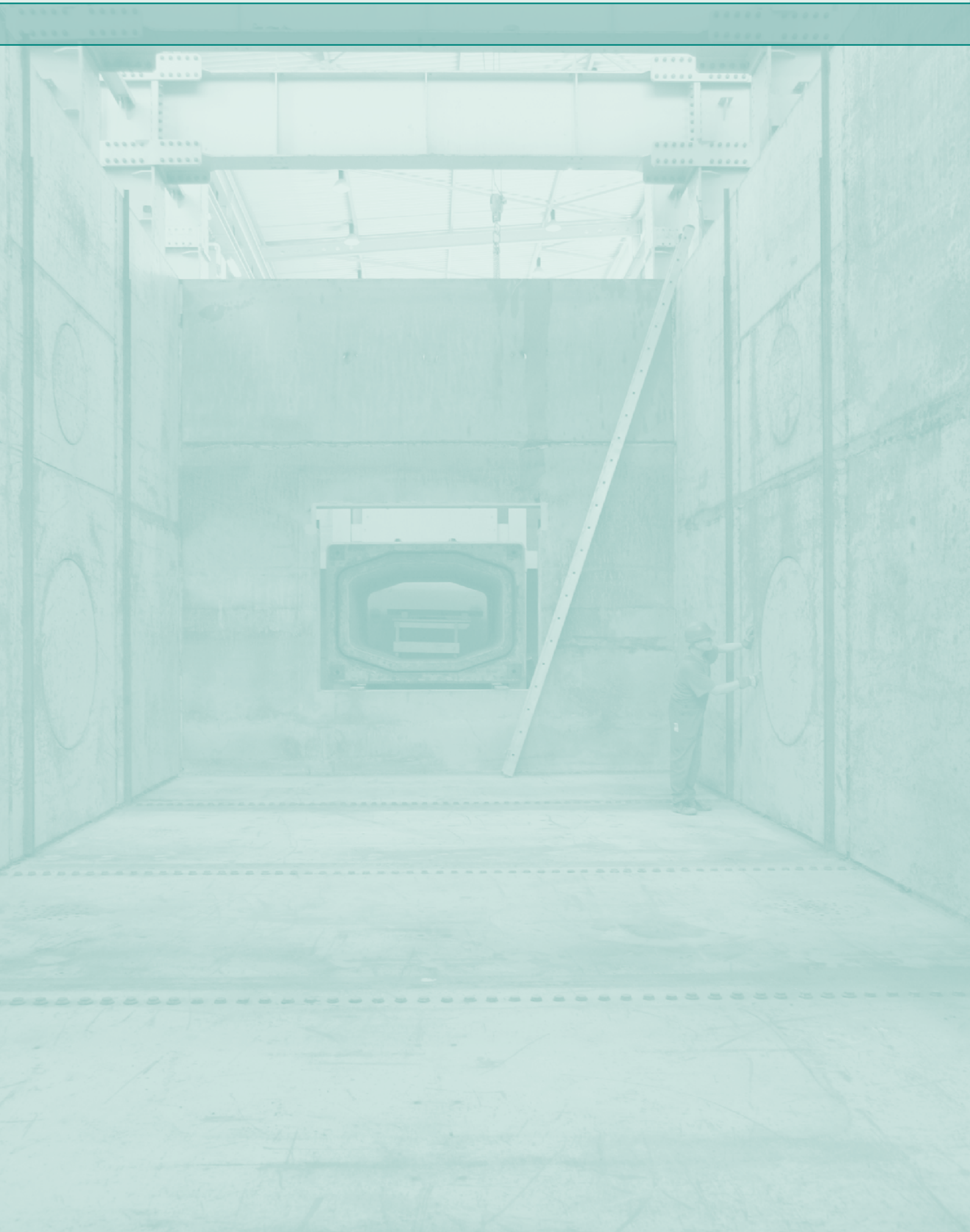


IKT Comparative Product-Test of repair methods for lateral connections

Members of the project steering commitee discuss the test apparatus

Do repaired lateral connections remain permanently watertight against infiltration? How do contractors, machinery and materials perform in practical tests? The results: varied right across the board, from VERY GOOD to DEFICIENT …

IKT recently performed an impartial, independent product test on rehabilitation of lateral connections. The background to this work is that damage to lateral connections has been the most common form of damage found in drain/sewer systems during DWA (German Association of Water, Wastewater and Waste) surveys for several years in a row. Damaged lateral connections can permit infiltration of soil and ground water, cause environmental harm and soil subsidence, and result in higher maintenance costs for network operators.

As many network operators are clearly aware, rehabilitation of lateral connections is necessary. But, the performance of contractors using different rehabilitation techniques is an area of great uncertainty for the network operators.

Project steering commitee

For this reason, just on twenty municipalities that operate sewer networks met in a steering commitee and conceived, together with IKT, a practically-orientated test programme. The aims were to comparatively evaluate the quality of contractors' performance and generate market pressure for performance improvement.

This IKT Comparative Product-Test was financed by the environment ministry of the German state of North Rhine-Westphalia (NRW) and by the members of the steering commitee. The steering commitee convened a total of nine times, to take all the crucial decisions concerning the project. These included specifying the contractors to be included, the nature and scope of the test programme, and the test criteria to be used. Finally, the group also performed the concluding evaluation of the results and awarded of grades.

Figure 1: Members of the municipal steering commitee define damage scenarios

Rehabilitation of lateral connections in ground water zones

The steering commitee decided to apply this IKT Product Test to two different test situations concerning leak tightness against infiltration:

- Case 1: Lateral reconnection
  to a liner-rehabilitated main sewer:
  - The test apparatus comprised a section of re-lined main sewer to which lateral connections needed to be re-connected.
- Case 2: Lateral connection repair
  in a non-rehabilitated main sewer:
  - Here, the test required damaged lateral connections were to be repaired, with no prior rehabilitation of the main sewer.

Selection of candidate contractors and market reaction

A market survey was undertaken which found that there are ten manufacturers of rehabilitation robots, and fifty-two rehabilitation contractor companies possessing the RAL-GZ 961, S10.1 to 4, QA system operating in the German market.

All of these contractors were invited to participate in the Comparative Test. They were also given the opportunity of obtaining on-the-spot detailed information on the test apparatus and the damage scenarios, and to quote for undertaking repairs on the test apparatus.

One manufacturer agreed to participate, whilst a second named a rehabilitation contractor in which it had confidence. Of the fifty-two rehabilitation contractors approached, eleven submitted a quotation, from which the steering commitee selected four. These six test candidates were paid for their work from the project budget.

IKT Comparative Test

Tab. 1: Contractors in the test	Case 1: Lateral reconnection to a liner-rehabilitated main sewer	Case 2: Lateral connection repair in a non-rehabilitated main sewer
IBG HydroTech GmbH	X	X
KATEC Kanaltechnik Müller & Wahl GmbH	X	X
Kuchem GmbH	X	X
PLITT-ROHRSANIERUNGSGESELLSCHAFT mbH	X	X
Swietelsky-Faber GmbH Kanalsanierung	X	X
Onyx Rohr- und Kanal-Service GmbH	X	
Geiger Kanaltechnik GmbH & Co. KG		X

All the other contractors either declined to participate for diverse reasons (e.g. alleged remoteness of the test apparatus from real practice, their systems being revised, deadline pressures and lack of capacity) or did not respond at all. The replies received from the manufacturers can be viewed in the full version of the project report (download: www.ikt.de/downloads/warentest-berichte, German version only). An overview of the companies participating in the tests is shown in Table 1.

Rehabilitation tasks and test programme

The system tests and quality assurance are the central elements in the test programme.

For the system tests for Case 1, „Lateral reconnection to a liner-rehabilitated main sewer", two lines of concrete pipe (DN 300), with concrete manholes (DN 1000) were installed in IKT's large-scale test facility, and a GRP or needle-felt (NF) CIPP liner was installed into them. Each pipe line was subdivided into six sections, such that each contractor was able to rehabilitate a section of both pipe lines each featuring three damage scenarios involving lateral connections of DN 150 vitrified clay pipe (Figure 2).

For Case 2, „Lateral connection repair in a non-rehabilitated main sewer", the test apparatus was installed in several medium-sized IKT test facilities. Each test apparatus comprised a manhole structure (DN 1000) consisting of prefabricated concrete elements and a DN 300 main sewer consisting in each case of a section of PVC piping connecting to sections of concrete and vitrified clay pipe. Six damage scenarios involving DN 150 vitrified clay pipe laterals (3 x concrete pipe, 3 x vitrified-clay pipe) were then simulated in each test facility.

The municipalities in the steering commitee defined the damage scenarios for both cases: defective, leaking sewer connections in various connection zones at the side, crown, and between the side and crown of the main sewer (Figure 2).

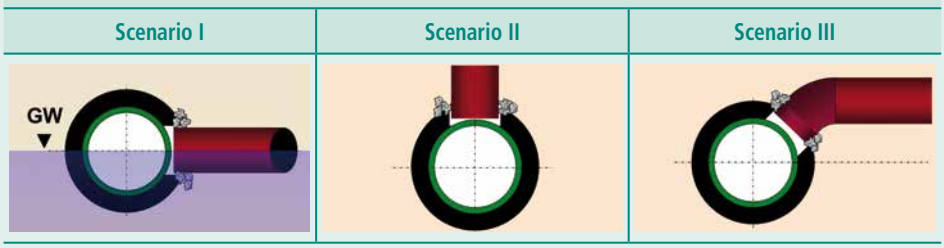
Each test apparatus was buried under sand such that the contractors could only access the pipe sections to be repaired via the manholes.

The rehabilitation objectives for the contractors were to restore the water tightness and correct functioning of the joint. Achieving this was left to each participant, i.e., they alone were responsible for the planning, conception, selection of materials, rehabilitation and finishing work. There was no time limit.

Test programme and evaluation system

The system tests started after completion of rehabilitation of the lateral connections. The prime emphasis here was on external water pressure (exclusion of ground water). In addition, operating loads caused by high-pressure (HP) cleaning were simulated, and any associated damage assessed by means of visual inspection.

Case 1: Lateral reconnection
Damage scenarios in a liner-rehabilitated main sewer
(in GRP and NF sections in each case)



Case 2: Lateral connection repair
Damage scenarios in a non-rehabilitated main sewer
(in concrete and vitrified-clay pipes in each case)

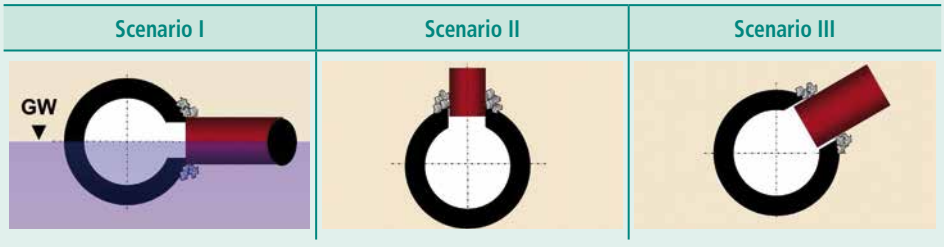


Figure 2: Damage scenarios for lateral reconnection and lateral connection repair, diagrams in principle

The essential elements of the tests were identical in both cases (lateral reconnection and lateral connection repair):

a) Application of external water-pressure load at a point two metres above the pipe crown
   - Short-term: < 72 h
   - Long-term: 4 months for lateral reconnection, 2 months for lateral connection repair

b) Sewer cleaning
   - standard HP operational load: approx. 80 bar at nozzle, 15 cycles

Additional information that was recorded, but not used in the evaluation and grading of performance, included how the repairs behaved under short-term and long-term groundwater exposure at 4.50 m head and after HP cleaning at approx. 100 bar at the nozzle, at 5 cycles. Internal-pressure tests were also performed after opening of the test lengths.

Water Tightness was evaluated on the basis of the observations made during the 2 m head short-term and long-term groundwater loading tests. Differentiation was made between three states:

- No abnormalities
- Perceptible abnormality in the form of visible discoloration and/or moisture
- Visible infiltration

Functionality determined whether the sewer's functional capability had been restored. For this each repaired point was visually assessed by the participating municipalities for stability and potential obstructions to sewer flow. Assessments were made after the repair was completed and following high pressure cleaning.

Contractor's quality assurance covered such criteria as their process manual, operator training (in use of robots), provision of test/inspection certificates for the material used, and supervision of the installation. The criterion of „no particular abnormalities" was included in the scoring to record, if necessary, any other special features of the performance of the activities.

The weighting of scores against these criteria is summarised in Table 2.

Validation of the test methodology

The operation of the rehabilitation methods used by the contractors was observed under practical conditions in the field, and performance was investigated using supplementary on-site tests, in order to validate the testing design at IKT's test facility. The essential installation operations were observed on site, the nature and scope of preparatory work recorded, and any deviations from the information contained in the process manuals and/or from the work performed at IKT test facilities noted.

Tab. 2: Evaluation system

System tests (85 %)	Quality Assurance (15 %)
Water Tightness (50 %): - Short-term GW exposure, 2.0 m (20 %) - Long-term GW exposure, 2.0 m (80 %) Additional information (collected but not included in the evaluation and grading) - Short- and long-term GW exposure, 4.50 m (only for liner-rehabilitated main sewer) - Internal-pressure tests after conclusion of test programme and removal of soil from around the test apparatus	- Process manual (20 %) - Operator training (20 %) - Test/inspection certificates for material used (20 %) - Contractor's supervision (20 %) - No particular abnormalities (20 %)
Functionality (50 %): - after completion (20 %) - after high-pressure cleaning (80 %) Additional information (collected but not included in the evaluation and grading) - Visible abnormality caused by maximum pressure HP cleaning (only for liner-rehabilitated main sewer)	

Test results, Case 1: „Lateral reconnection"

Kuchem GmbH achieved the best result for „Lateral reconnection to a liner-rehabilitated main sewer", with the grade of VERY GOOD. Contractors KATEC Kanaltechnik Müller & Wahl GmbH, Swietelsky-Faber GmbH Kanalsanierung, and PLITT-ROHRSANIERUNGS-GESELLSCHAFT mbH each achieved a GOOD grading. A ADEQUATE grade was achieved by Onyx Rohr- und Kanal-Service GmbH. IBG HydroTech GmbH A was graded as DEFICIENT and the evaluation identified a clear need for further optimisation of its relatively recently developed robot system.

Water Tightness

Where a damaged connection had visually been assessed to be correctly rehabilitated and was initially water tight, it was generally found that they also remained so throughout the testing. Twenty lateral connections (59% of the 34 repairs undertaken) exhibited no abnormalities in terms of Water Tightness up to the end of the testing (including the long-term groundwater simulation at 4.50 m head).

Lateral connections with visually conspicuous irregularities, such as missing material at the point of damage or highly textured surfaces (8 of 34 repairs, approx. 24 %) were found not to be water tight as early as the short-term groundwater simulation at 2 m. Under long-term groundwater simulation at 2 m there was no significant further deterioration in their condition in terms of infiltration. Seven other lateral connections did, however, exhibit new abnormalities, in the form of visible moisture and/or discoloration.

Long-term exposure

Up to the end of the external water-pressure tests, a further deterioration in infiltration performance was observed only in one individual case, even under the significant rise in the water table to 4.5 m. At the end of the programme of testing, nine of thirty-four repaired sewer laterals (approx. 26 %) manifested visible infiltration.

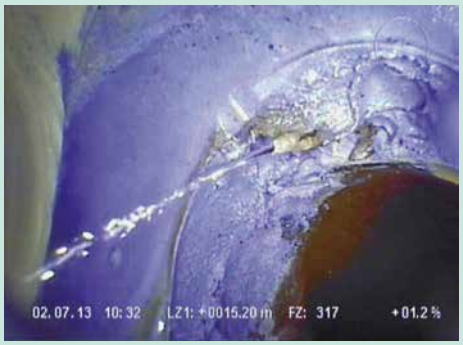
Examples of evaluations following long term water tightness testing are shown in Figure 3.

A: Tight lateral connection in the GRP lined pipe

B: Tight lateral connection in the NF lined pipe

C: Discoloration

D: Moisture, with no infiltration



E: Leaking lateral connection (jet of water)

F: Leaking lateral connection (gushing water)

Figure 3: „Tightness" test criterion after long-term groundwater simulation test for „Lateral reconnection to a liner-rehabilitated main sewer"

Five of the thirty-four lateral connections (approx. 15 %) exhibited abnormalities in the form of discoloration or moisture; and continued observation of these lateral connections would appear recommendable in practice. It should be noted, however, that HP cleaning is capable of removing these marks and that these abnormalities are then no longer perceptible. However, no waste-water was being fed through the test apparatus and in reality this may cause significant discoloration to the liner and the rehabilitated lateral connection, complicating or preventing identification of infiltration-induced abnormalities.

Figure 3 Photopgraphs A-F show examples of evaluations for the Water Tightness criterion of re-connected laterals following the long-term groundwater simulation test.

Functionality

For the Functionality criterion (Table 3), no significant differences were apparent in the liner-rehabilitated main sewer between the GRP lined pipe (average overall grade: 2.7) and the NF lined pipe (average overall grade: 2.8). Serious differences are apparent between the test participants, as gradings ranged from 1.7 to 5.1. Four contractors achieved a GOOD grade, one a SATISFACTORY grade and one was graded DEFICIENT.

Figure 4: The best-graded lateral connection for the „Functionality" criterion, in each case after HP cleaning; GRP lined pipe (left); NF lined pipe (right)

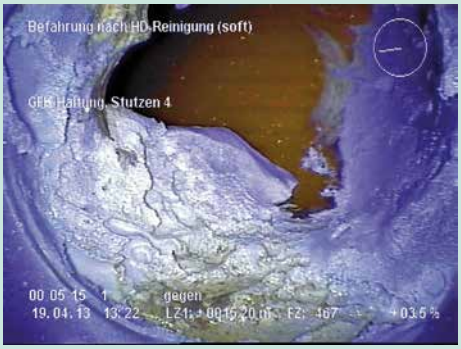
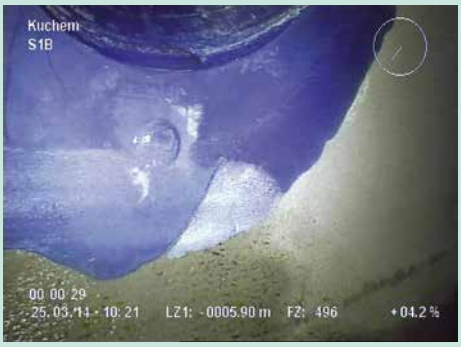


Figure 5: Poorest-graded lateral connection for the „Functionality" criterion, in each case after HP cleaning; GRP lined pipe (left); NF lined pipe (right)

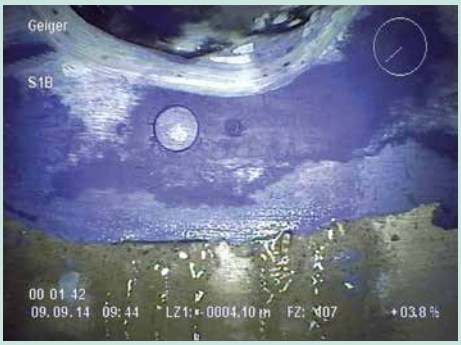
A: Tight lateral connection in concrete pipe

B: Tight lateral connection in vitrified-clay pipe



C: Moisture, with no infiltration, Example 1

D: Moisture, with no infiltration, Example 2



E: Leaking lateral connection in concrete pipe

F: Leaking lateral connection in vitrified-clay pipe

Figure 6: Repaired lateral connections in non- rehabilitated main sewer after long-term groundwater simulation

High-Pressure cleaning

Only minimal variations in grades, by a maximum of 0.3 points, were apparent after HP cleaning. It is notable that only slight visual abnormalities, in the form of spalling of material at the repaired lateral connections, occurred as a result of cleaning. This was observed more frequently in the NF lined pipe (13 of 18 lateral connections). Spalling was apparent only on two of eighteen lateral connections in the GRP lined pipe. Such spalling is generally harmless in terms of sewer functionality.

Damage Scenario I, at a 45° angle to the longitudinal axis (Figure 2) in relation to influx of groundwater was found to be the most difficult exercise for the majority of participants. No particular differences were noticeable between Damage Scenarios II and III.
Examples of evaluations against the Functionality criterion are illustrated in Figures 4 and 5 for the best- and the poorest-graded lateral connection after HP cleaning in the GRP and NF lined test pipes.

The contractors' quality assurance scored well with only a few areas of criticism. All results are compiled in Table 3.

Test results, Case 2: „Lateral connection repair"

KATEC Kanaltechnik Müller & Wahl GmbH and Kuchem GmbH both achieved the best result (Grade: 1.6) in the „Lateral connection repair in a non-rehabilitated main sewer" testing (Table 4). They are followed by PLITT-ROHRSANIERUNGS-GESELLSCHAFT mbH, with a grade of GOOD (2.2). Swietelsky-Faber GmbH Kanalsanierung and Geiger Kanaltechnik GmbH & Co. KG were graded SATISFACTORY. IBG HydroTech GmbH with its relatively recently developed robot system again exhibited a significant need for optimisation of its technique, and just achieved an ADEQUATE grade.

Where a lateral connection was visually determined to have been satisfactorily rehabilitated and was initially water tight, it generally remaind so. Approx. 67 % (24 of 36) rehabilitated laterals exhibited no abnormalities in terms of Water Tightness up to the end of the tests.

Long-term exposure

Up to the end of the external water-pressure exposure tests, only one further deterioration involving infiltration was observed, even after the significant increase in the length of exposure to groundwater. Seven of the thirty-six rehabilitated sewer laterals (approx. 19 %) exhibited infiltration at the end of the test programme.

Figure 7: The best-graded lateral connection for the „Functionality" criterion, after HP cleaning in each case; concrete pipe (left); vitrified-clay pipe (right)

Figure 8: The poorest-graded lateral connection for the „Functionality" criterion, after HP cleaning in each case; concrete pipe (left); vitrified-clay pipe (right)

Five of the thirty-six lateral connections (approx. 14 %) exhibited abnormalities in the form of moisture. A risk is therefore present here and further observation of these lateral connections would appear advisable in practice.

Figure 6 Photographs A-F show examples of evaluations of lateral repairs after long-term groundwater simulation.

Functionality

No significant differences were apparent for the Functionality criterion between the repairs on concrete pipe (average overall grade: 2.5) and vitrified-clay pipe (average overall grade: 2.6). Significant differences were observed between the various contractors with grades varying from 1.9 to 3.6. Four were graded GOOD, one SATISFACTORY and one ADEQUATE.

Only minimal variations in the grades, by a maximum of 0.2 points, occurred after HP cleaning. As with the lateral reconnection scenarios, the rehabilitation of Damage Scenario I, involving a 45° angle to the longitudinal axis and influx of groundwater (Figure 2), proved to be the most difficult exercise for the majority of contractors. There were no significant differences in the case of Damage Scenarios II and III.

Examples of evaluations of lateral repairs against the Functionality criterion are shown in Figures 7 and 8 for the best and poorest results after HP cleaning in the concrete and the vitrified-clay main sewer pipes.

The contractors' quality assurance arrangements were found to be predominantly good and as with the lateral re-connections only a few points were criticised. All results are compiled in Table 4.

Conclusion

Lateral connection rehabilitation is reliably possible

The contractors participating in this IKT Product Test demonstrated that reliable sealing of lateral connections is possible, both in the „Lateral reconnection to a liner-rehabilitated main sewer" and in the „Lateral connection repair in a non-rehabilitated main sewer" cases. However, the range of performance across the contractors is extremely broad, from VERY GOOD to DEFICIENT.

Market reactions

It is surprising that only two of the ten manufacturers and eleven of the fifty-two rehabilitation contractors approached, were prepared to participate in this Comparative Test. This may, in part, be due to time and availability constraints, but IKT did offer a wide range of dates for installation. Many companies were unwilling to confront the rehabilitation tasks presented, and instead criticised the test conditions. This is despite these testing conditions being designed in agreement with the members of municipal sewer network operator steering commitee, to be extremely practically orientated and based on many years of on-site experience.

Groundwater useful for quality control

Where the rehabilitation results from the tests indicated a good quality immediately after completion of the rehabilition, no new quality deficiencies were generally observed after long term exposure to groundwater and after HP cleaning. The practical conclusion to be drawn is that acceptance inspection should best be performed only when groundwater is present. If no infiltration is then apparent at the lateral connection, the rehabilitation/repair work can be assumed with high probability to have been successful.

Lateral reconnection and lateral connection repair achieve similar results

Despite the serious differences between the contractors on rehabilitation quality, the results they achieved for the two applications studied were very similar.

Sewer cleaning has no particular influence on performance

No abnormalities were found in the non-rehabilitated main sewer (lateral connection repair) after completion of the HP sewer cleaning test. Spalling was observed in many cases in the liner-rehabilitated main sewer (lateral reconnection), but these instances would have no significant effects on the leak tightness and functionality of the rehabilitated lateral connections.

Further tests being prepared

Equipment manufacturers and rehabilitation contractors showed great interest in the definitive quality requirements of the municipalities from the development phase of the test programme onwards. The test programme devised for this project and now made generally available, provides for the first time a set of comparative product tests for the „Lateral connection rehabilitation in groundwater zones" application. These now form the basis for the award of IKT's „Lateral reconnection" and „Lateral connection repair" Product Test seals.

Test report for download

The detailed test report is available (German version only) on the Internet for free-of-charge download, see:
www.ikt.de/downloads/warentest-berichte

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IKT – Institute for Underground Infrastructure

Table 3. Results, Case 1: Lateral reconnection to a liner-rehabilitated main sewer

IKT Comparative Product-Test of repair methods for lateral connections

Rehabilitation task: Rehabilitation of three damage scenarios in each case in a liner-rehabilitated concrete main sewer (DN 300)

- Damage Scenario I: "Defective (leaking) sewer connection" at the side zone of the main sewer (45° angle to/in the main sewer's longitudinal axis); DN 150 vitrified-clay pipe is presented up to the concrete pipe (main sewer); influx of groundwater at start of rehabilitation
- Damage Scenario II: "Defective (leaking) sewer connection" at the crown of the main sewer (90° angle to the longitudinal axis of the main sewer); DN 150 vitrified-clay pipe is inserted into the concrete pipe (main sewer) at a distance from the CIPP liner of approx. 2 cm
- Damage Scenario III: "Defective (leaking) sewer connection" between side zone and crown of the main sewer (45° bend outgoing perpendicular to the longitudinal axis of the main sewer): DN 150 vitrified-clay pipe is inserted (to approx. half wall thickness of the concrete pipe) into the concrete pipe (main sewer)

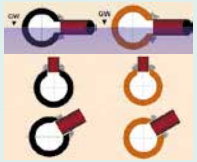
Contractor	**Kuchem GmbH**	**KATEC Kanaltechnik Müller & Wahl GmbH**	**Swietelsky-Faber GmbH Kanalsanierung**	**PLITT-ROHRSANIERUNGS-GESELLSCHAFT mbH**	**Onyx Rohr- und Kanal-Service GmbH**	**IBG HydroTech GmbH[1]**
Robot-based method using • Resin system	KA-TE PMO with • EPOXONIC Ex 1824 rapid	KA-TE PMO with • EPOXONIC Ex 1013 • EPOXONIC Ex 1824 rapid • MC BAUCHEMIE Konodur Robopox 10	KA-TE PMO with • resinnovation Harz 10	KA-TE PMO with • Sika Robotec 61	KA-TE PMO with • EPOXONIC Ex 1355 • EPOXONIC Ex 1824 rapid	IBG HydroCut injection system with • EPOXONIC Ex 1824 rapid
IKT test results	**VERY GOOD (1.5)**	**GOOD (1.6)**	**GOOD (2.0)**	**GOOD (2.3)**	**ADEQUATE (3.9)**	**DEFICIENT (5.0)**
System tests in test lengths (85 %)	**Good (1.6)**	**Good (1.8)**	**Good (2.0)**	**Good (2.5)**	**Adequate (4.0)**	**Inadequate (5.6)**
Functionality[2] (50 %)	**2.2**	**2.1**	**2.2**	**1.7**	**3.2**	**5.1**
after completion (20 %)	2.2	1.9	2.1	1.6	3.2	5.1
after HP cleaning (80 %)	2.2	2.2	2.2	1.7	3.2	5.1
Tightness[3] (50 %)	**1.0**	**1.4[4]**	**1.8**	**3.3**	**4.8**	**6.0[4]**
Short-term groundwater exposure 2.0 m (20 %)	1.0	1.0	1.0	2.5	4.0	6.0
Long-term groundwater exposure 2.0 m (80 %)	1.0	1.5	2.0	3.5	5.0	6.0
Quality assurance[5] (15 %)	**Very Good (1.0)**	**Very Good (1.0)**	**Good (2.0)**	**Very Good (1.0)**	**Satisfactory (3.0)**	**Good (2.0)**
Process manual (20 %)	+	+	+	+	+	+
Operator training (20 %)	+	+	+	+	-	+
Test certificates for materials used (20 %)	+	+	- (no DIBt approval)	+	+	+
Third-party supervision (20 %)	+	+	+	+	+	-
No particular abnormalities (20 %)	+	+	+	+	- (Material use-by date expired)	+
Additional information: Impression from on-site investigations	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	No date possible	No date stated
External water-pressure load 4.50 m	6x no problem	4x no problem, 1x infiltration, 1x not evaluated	4x no problem, 2x discoloration/moisture	4x no problem, 2x discoloration/moisture	2x no problem, 3x infiltration, 1x discoloration/moisture	5x infiltration, 1x not evaluated
Internal pressure testing at 0.5 bar after completion of the test programme and opening	5x tight, 1x not tight	3x tight, 1x not tight, 2x not evaluated	3x tight, 3x not tight	2x tight, 3x not tight, 1x not evaluated	3x tight, 3x not tight	5x not tight, 1x not evaluated
Visually apparent abnormalities from HP cleaning (max.)	6 abnormalities	3 abnormalities	No abnormalities	3 abnormalities	1 abnormality	No abnormalities
Year of manufacture of robot	approx. 1997	approx. 2008	2011	not known	approx. 1992	approx. 2012
Days of use on site	2,5 days	3.5 days	3 days	3.5 days	4.5 days	4.5 days
Time needed for rehabilitation (cutting) of 6 lateral connections (ca.)	9.3 hours (7.1 hours)	13.0 hours (4.6 hours)	16.5 hours (7.6 hours)	15.8 hours (11.0 hours)	21.1 hours (7.3 hours)	26.8 hours (3.8 hours)[6]
Material consumption for 6 lateral connections (ca.)	30 kg	34 kg	32 kg	41 kg	32 kg	27 kg
Costs per lateral connection (net)/ depot (ca.)	670 €/ NRW	810 €/ NRW	880 €/ NRW	630 €/ Lower Saxony	650 €/ Lower Saxony	440 €/ Hesse

1 All cutting work was performed by contractor Horst Drzysga; this company also supplied the equipment for further work.
2 Evaluation using visual assessment by municipalities by means of award of grades (1-6); decimal places permissible (20 % weighting after completion; 80 % weighting after HP cleaning)
3 Evaluation on the basis of external water-pressure exposure. Grades awarded by points: No infiltration 0/green; Problems – 0.5/yellow; Perceptible infiltration – 1.5/red. 0 points = 1.0; 1 point = 2.0; 2 points = 3.0; 3 points = 4.0; 4 points = 5.0; above 5 points = 6.0
4 Damage Scenario 2, NF lined pipe,, not evaluated due to cracking in connecting sewer (causes not clearly apparent)
5 Evaluation: "+"= demonstrated; "-"= deficient; Approval/Certificates/Analyses must apply to the materials used in the test
6 Three lateral connections were injected a second time

Evaluation key for test results: Very Good = 1.0 - 1.5. Good = 1.6 - 2.5. Satisfactory = 2.6 - 3.5. Adequate = 3.6 - 4.5. Deficient = 4.6 - 5.5. Inadequate = 5.6 - 6.0

Table 4. Results, Case 2: Lateral connection repair in a non-rehabilitated main sewer

IKT Comparative Product-Test of repair methods for lateral connections



Rehabilitation task: Rehabilitation of three damage scenarios in each case in a non-rehabilitated concrete and non-rehabilitated vitrified-clay main sewer (DN 300)

- Damage Scenario I: "Defective (leaking) sewer connection" at the side zone of the main sewer (45° angle to/in the main sewer's longitudinal axis); DN 150 vitrified-clay pipe is presented up externally to the concrete/vitrified-clay pipe (main sewer). Groundwater influx at start of rehabilitation
- Damage Scenario II: "Defective (leaking) sewer connection" at the crown of the main sewer (90° angle to the main sewer's longitudinal axis); DN 150 vitrified-clay pipe is inserted to half the sewer's wall thickness into the concrete/vitrified-clay pipe (main sewer)
- Damage Scenario III: "Defective (leaking) sewer connection" between side zone and crown of the main sewer (45° angle outgoing perpendicular to the main sewer's longitudinal axis); DN 150 vitrified-clay pipe is inserted into the concrete/vitrified-clay pipe (main sewer); max. inward projection: 1 cm

Contractor	KATEC Kanaltechnik Müller & Wahl GmbH	Kuchem GmbH	PLITT-ROHRSANIERUNGS-GESELLSCHAFT mbH	Swietelsky-Faber GmbH Kanalsanierung	Geiger Kanaltechnik GmbH & Co.KG	IBG HydroTech GmbH[1]
Robot-based method using • Resin system	KA-TE PMO with • EPOXONIC Ex 1824 rapid • MC BAUCHEMIE Konodur Robopox 10	KA-TE PMO with • EPOXONIC Ex 1824 rapid	KA-TE PMO with • Sika Robotec 61	KASRO with • MC BAUCHEMIE KonudurRobopox CI	KA-TE PMO with • EPOXONIC Ex 1824 rapid	IBG HydroCut injection system with • resinnovation Harz 10
IKT test result	**GOOD (1.6)**	**GOOD (1.6)**	**GOOD (2.2)**	**SATISFACTORY (2.7)**	**SATISFACTORY (3.2)**	**ADEQUATE (4.5)**
System tests in test lengths (85 %)	**Good (1.7)**	**Good (1.7)**	**Good (2.4)**	**Satisfactory (2.8)**	**Satisfactory (3.5)**	**Deficient (4.7)**
Functionality[2] (50 %)	**2.4**	**2.0**	**1.9**	**2.2**	**3.1**	**3.6**
after completion (20 %)	2.3	1.9	1.9	2.1	3.0	3.5
after HP cleaning (80 %)	2.4	2.0	1.9	2.2	3.1	3.7
Tightness[3] (50 %)	**1.0**	**1.5**	**3.0**	**3.5**	**4.0**	**5.8**
Short-term groundwater exposure 2.0 m (20 %)	1.0	1.5	3.0	3.5	4.0	5.0
Long-term groundwater exposure 2.0 m (80 %)	1.0	1.5	3.0	3.5	4.0	6.0
Quality assurance[4] (15 %)	**Very Good (1.0)**	**Very Good (1.0)**	**Very Good (1.0)**	**Good (2.0)**	**Very Good (1.0)**	**Satisfactory (3.0)**
Process manual (20 %)	+	+	+	-	+	+
Operator training (20 %)	+	+	+	+	+	+
Test certificates for the materials used (20 %)	+	+	+	+	+	- (no DIBt approval)
Third-party supervision (20 %)	+	+	+	+	+	-
No particular problems (20 %)	+	+	+	+	+	+
Additional information: Impression from on-site investigations	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	No date stated
Internal-pressure test at 0.5 bar after completion of the test programme and opening	6x tight	6x tight	4x tight, 2x not tight	5x tight, 1x not tight	5x tight, 1x not tight	2x tight, 4x not tight
Year of manufacture of robot	approx. 2008	approx. 1997	Not known	2012	approx. 2003	approx. 2013
Days of use on site	4 days	2 days	3 days	2 days	2 days	4 days
Time needed for rehabilitation (cutting) of 6 lateral connections (ca.)	7.8 hours (3.2 hours)[5]	5.4 hours (2.6 hours)	11.3 hours (5.0 hours)	13.8 hours (8 hours)[6]	9.2 hours (3.7 hours)[6]	11 hours (4.6 hours)[7]
Material consumption for 6 lateral connections (ca.)	24 kg	16 kg	48 kg	55 kg	28 kg	22 kg
Costs per lateral connection (net)/ depot (ca.)	720 €/ NRW	670 €/ NRW	700 €/ Lower Saxony	920 €/ NRW	830 €/ NRW	440 €/ Hesse

1 The complete repair scope was performed by IBG. Use was made of equipment supplied by the Horst Drzysga company only for the cutting work.
2 Evaluation based on visual assessment by municipalities by means of award of grades (1-6). Decimal places permissible (20 % weighting after completion; 80 % weighting after HP cleaning)
3 Evaluation on the basis of external water-pressure exposure. Grades awarded by points: No infiltration 0/green; Problems – 0.5/yellow; Perceptible infiltration – 1.5/red. 0 points = 1.0; 1 point = 2.0; 2 points = 3.0; 3 points = 4.0; 4 points = 5.0; above 5 points = 6.0
4 Evaluation: "+"= demonstrated; "-"= deficient; Approval/Certificates/Analyses must apply to the materials used in the test
5 One lateral connection was injected a second time
6 Two lateral connections were injected a second time
7 Five lateral connections were injected a second time

Evaluation key for test results: Very Good = 1.0 - 1.5. Good = 1.6 - 2.5. Satisfactory = 2.6 - 3.5. Adequate = 3.6 - 4.5. Deficient = 4.6 - 5.5. Inadequate = 5.6 - 6.0.

Slight disappointment on wall thickness

CIPP liner samples from six countries tested. Test results still at high level. Only wall thicknesses are more frequently below target. Most non-German companies also score well.

Precision measurement necessary: wall thicknesses differ

The IKT - Institute for Underground Infrastructure hereby presents its twelfth annual LinerReport. The report is based on just on 2,150 CIPP-liner samples taken for qualitycontrol purposes on project sites and tested by the IKT CIPP Liner Test Centre in 2015.

The 2015 data-base

The 2015 IKT LinerReport comprises the results of those contractors from which the IKT has tested not less than twenty-five liner samples of one liner type obtained from five different sites. This requirement is met this year by twenty-four companies, six more than in the previous year. Five of these companies are represented by more than one liner type. Thirteen of them are active in Germany, five in the Netherlands and two in each of Austria and Switzerland. For the first time, one company from the United Kingdom and one from the Czech Republic are included in the test programme.

In 70% of all cases, the project clients (or their engineering consultancies) commissioned the IKT directly to perform laboratory testing of liner samples. Only 30% of the orders originated from the contractors themselves (see Table 1).

Target/Actual analysis

Four characteristics are analysed for each of the samples taken on site: modulus of elasticity, flexural strength, wall thickness and water-tightness. The Actual data is compared against the Target data from the DIBt (German Institute for Building Technology) approvals and against any divergent Target specifications by the client. The Target values for wall thickness are either defined on the basis of structural-analysis calculations or are specified by the client. Two procedures are used for the testing of the water-tightness of needle-felt liners: with and without cutting of the inner film. The latter method is selected for liners, the DIBt approval - or, in the Netherlands, the KOMO Foundation certificate - for which confirms the inner film as an integral element with an influence on tightness. The inner film of all other needle-felt liners is cut. GRP liners which do not have an inner film which remains in the sewer are tested without cutting.

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, Part 4/DIN EN 13566, Part 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, Part 4** using a precision slide gauge

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, Part 4/DIN EN 13 566, Part 4* (short-term flexural strength)

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 throug
- Test period: 30 min.

Results: see Table 5

A detailed description of these tests can be found on www.ikt-online.org/cipp-liner

* DIN EN ISO 11296, Part 4 superseded DIN EN 13566, Part 4 with effect from July 2011. The test results are nonetheless evaluated in acc. with DIN EN 13566, Part 4 for a number of liner systems, since the Target data for the mechanical properties (national technical approvals) were determined in accordance with this standard.

** Determination of combined thickness remains unchanged in DIN EN ISO 11296, Part 4 vis-à-vis DIN EN 13566, Part 4.

Table 1: Contractors and liner systems, 2015

Contractors	Liner systems	Liner type	Number of samples	IKT testing commissioned by	
				Contractor %	Client %
Aarsleff Rohrsanierung GmbH	iMPREG liner	GRP	178	0	100
Aarsleff Rohrsanierung GmbH	PAA SF-liner	NF	114	0	100
Arkil Inpipe GmbH	Berolina liner	GRP	155	0	100
Arkil Inpipe GmbH	SAERTEX liner	GRP	65	0	100
Arpe AG (CH)	Alphaliner	GRP	26	4	96
Erles Umweltservice GmbH	iMPREG liner	GRP	46	15	85
Geiger Kanaltechnik GmbH & Co.KG	Alphaliner	GRP	84	29	71
Geiger Kanaltechnik GmbH & Co.KG	Berolina liner	GRP	36	56	44
GMB Rioleringstechnieken B.V. (NL)	iMPREG liner	GRP	37	35	65
Hamers Leidingtechniek B.V. (NL)	Alphaliner	GRP	104	0	100
HF-Rohrtechnik GmbH (A)	Berolina liner	GRP	48	0	100
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner (NL)* Netherlands	NF	106	5	95
ISS Kanal Services AG (CH)	Alphaliner	GRP	41	83	17
Jeschke Umwelttechnik GmbH	Alphaliner	GRP	45	78	22
Jeschke Umwelttechnik GmbH	Brandenburger liner	GRP	114	42	58
Kanaltechnik Agricola GmbH	iMPREG liner	GRP	39	90	10
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	GRP	43	0	100
KTF GmbH	iMPREG liner	GRP	100	91	9
Pfaffinger Rohrnetz- & Sanierungstechnik GmbH	iMPREG liner	GRP	37	0	100
Sanierungstechnik Dommel GmbH	Alphaliner	GRP	43	79	21
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	GRP	29	55	45
Swietelsky-Faber Kanalsanierung GmbH (A)	Brandenburger liner	GRP	25	0	100
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	GRP	54	100	0
TKT GmbH &Co.KG	Alphaliner	GRP	249	18	82
Trasko a.s. (CZ)	Alphaliner	GRP	45	100	0
Umwelttechnik und Wasserbau GmbH	Alphaliner	GRP	161	38	62
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	GRP	56	55	45
UKDN Waterflow Ltd. (GB)	iMPREG liner	GRP	27	100	0
Van der Velden Rioleringsbeheer B.V. (NL)	iMPREG liner	GRP	41	20	80
Total			**2,148**	**30**	**70**

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

* The Insituform CIPP liner (NL) has held the Dutch KOMO Foundation product certificate since 15 September 2014

Table 2: Test results for modulus of elasticity, 2015 (short-term flexural modulus)

Contractors	Liner systems	2015		2014	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Aarsleff Rohrsanierung GmbH	iMPREG liner	178	100.0	100	◂▸
Arkil Inpipe GmbH	Berolina liner	155		100	◂▸
Arpe AG (CH)	Alphaliner	26		-	-
Erles Umweltservice GmbH	iMPREG liner	46		100	◂▸
Geiger Kanaltechnik GmbH & Co. KG	Berolina liner	36		100	◂▸
GMB Rioleringstechnieken B.V. (NL)	iMPREG liner	36		-	-
Hamers Leidingtechniek B.V.(NL)	Alphaliner	104		100	◂▸
HF-Rohrtechnik GmbH (A) using Berolina liner	Berolina liner	48		-	-
ISS Kanal Services AG (CH)	Alphaliner	41		100	◂▸
Jeschke Umwelttechnik GmbH	Alphaliner	45		100	◂▸
Jeschke Umwelttechnik GmbH	Brandenburger liner	114		100	◂▸
Kanaltechnik Agricola GmbH	iMPREG liner	39		100	◂▸
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	43		-	-
KTF GmbH	iMPREG liner	100		100	◂▸
Pfaffinger Rohrnetz- & Sanierungstechnik GmbH	iMPREG liner	37		-	-
Swietelsky-Faber Kanalsanierung GmbH (A)	Brandenburger liner	24		-	-
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	54		-	-
Trasko a.s. (CZ)	Alphaliner	45		-	-
Umwelttechnik und Wasserbau GmbH	Alphaliner	161		97.8	▲
UKDN Waterflow Ltd. (GB)	iMPREG liner	27		-	-
TKT GmbH & Co. KG	Alphaliner	249	99.6	99.3	▲
Aarsleff Rohrsanierung GmbH	PAA SF liner	114	99.1	96.9	▲
Average			**99.1**	**98.7**	▲
Van der Velden Rioleringsbeheer B.V. (NL)	iMPREG liner	41	97.6	93.5	▲
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	29	96.6	-	-
Geiger Kanaltechnik GmbH & Co. KG	Alphaliner	84	96.4	-	-
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	55	96.4	-	-
Arkil Inpipe GmbH	SAERTEX liner	64	95.3	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner	106	95.3	95.7	▼
Sanierungstechnik Dommel GmbH	Alphaliner	43	95.3	-	-

* Target values as per client's data (structural-analysis/sample data record) | – Not evaluated, too few liner samples

Three-point bending test on CIPP liners

Table 3: Test results for flexural strength, 2015 (short-term -σ_{fb})

Contractors	Liner systems	2015		2014	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Aarsleff Rohrsanierung GmbH	iMPREG liner	178	100.0	100	◂▸
Arkil Inpipe GmbH	Berolina liner	155		100	◂▸
Arpe AG (CH)	Alphaliner	26		-	-
Erles Umweltservice GmbH	iMPREG liner	46		100	◂▸
Geiger Kanaltechnik GmbH & Co.KG	Alphaliner	84		-	-
Geiger Kanaltechnik GmbH & Co.KG	Berolina liner	36		100	◂▸
Hamers Leidingtechniek B.V.(NL)	Alphaliner	104		100	◂▸
HF-Rohrtechnik GmbH (A)	Berolina liner	48		-	-
ISS Kanal Services AG (CH)	Alphaliner	41		100	◂▸
Jeschke Umwelttechnik GmbH	Alphaliner	45		100	◂▸
Jeschke Umwelttechnik GmbH	Brandenburger liner	114		100	◂▸
Kanaltechnik Agricola GmbH	iMPREG liner	39		100	◂▸
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	43		-	-
KTF GmbH	iMPREG liner	100		100	◂▸
Pfaffinger Rohrnetz- & Sanierungstechnik GmbH	iMPREG liner	37		-	-
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	29		-	-
Swietelsky-Faber Kanalsanierung GmbH (A)	Brandenburger liner	24		-	-
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	54		-	-
TKT GmbH & Co. KG	Alphaliner	249		100	◂▸
Trasko a.s. (CZ)	Alphaliner	45		-	-
Average			**99.3**	**98.7**	▲
Umwelttechnik und Wasserbau GmbH	Alphaliner	161	98.8	97.8	▲
Arkil Inpipe GmbH	SAERTEX liner	64	98.4	-	-
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	55	98.2	-	-
Sanierungstechnik Dommel GmbH	Alphaliner	43	97.7	-	-
Aarsleff Rohrsanierung GmbH	PAA SF-liner	114	97.4	99.2	▼
GMB Rioleringstechnieken B.V. (NL)	iMPREG liner	36	97.2	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner	106	97.2	92.8	▲
UKDN Waterflow Ltd. (GB)	iMPREG liner	27	96.3	-	-
Van der Velden Rioleringsbeheer B.V. (NL)	iMPREG liner	41	95.1	93.5	▲

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

Modulus of elasticity very good

The majority of contractors achieved very good results for the test criterion „modulus of elasticity", an indicator of the liners' load-bearing capacity. This test was passed by 99.1% of the site samples, slightly above (by +0.4 percentage points) the already excellent level achieved in the previous year. With the exception of just one contractor, all managed to at least maintain or even improve their 2014 performance. Particularly worthy of note is the fact that 100% of the samples fulfilled this criterion in twenty of twenty-nine cases.

Flexural strength also very good

An even better result than in the case of modulus of elasticity is actually apparent for the criterion of flexural strength, which denotes the point at which the liner fails as a result of excessively high stress: 99.3% of the site samples achieve the specified Target values, also an improvement (+0.6%P) over the already extremely good results for last year. As in the case of modulus of elasticity, this test criterion is 100% achieved in twenty of twenty-nine instances. With one exception, all the contractors also maintained or improved on their results for the previous year.

Wall thickness slightly poorer

Wall thickness which, together with the modulus of elasticity, determines the stiffness of a liner, results in a less positive picture than for the first two test criteria: the average for all samples passing the test has fallen by 1.4 percentage points (%P) compared to the previous year, to 95.4%. In thirteen of twenty-four cases, 100% of the samples fulfil this criterion. Eight contractors nonetheless managed to maintain or improve their previous year's score, while five, on the other hand, performed less well - one of them very significantly, with a minus of 19 %P compa-

Table 4: Test results for wall thickness, 2015 (average combined thickness in acc. with DIN EN ISO 11296, Part 4)

Contractors	Liner systems	2015		2014	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Arkil Inpipe GmbH	Berolina liner	56		97.6	↑
Arkil Inpipe GmbH	SAERTEX liner	56		-	-
Arpe AG (CH)	Alphaliner	11		-	-
Erles Umweltservice GmbH	iMPREG liner	35		100	↔
Geiger Kanaltechnik GmbH & Co.KG	Berolina liner	16		91.7	↑
Hamers Leidingtechniek B.V.(NL)	Alphaliner	104		100	↔
Jeschke Umwelttechnik GmbH	Alphaliner	45	100.0	98.7	↑
Jeschke Umwelttechnik GmbH	Brandenburger liner	114		100	↔
Kanaltechnik Agricola GmbH	iMPREG liner	39		100	↔
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	13		-	-
Pfaffinger Rohrnetz- & Sanierungstechnik GmbH	iMPREG liner	36		-	-
Sanierungstechnik Dommel GmbH	Alphaliner	42		-	-
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	54		-	-
KTF GmbH	iMPREG liner	100	99.0	100	↓
ISS Kanal Services AG (CH)	Alphaliner	40	97.5	96.3	↑
Umwelttechnik und Wasserbau GmbH	Alphaliner	65	96.9	97.9	↓
Average			**95.4**	**96.8**	↓
Geiger Kanaltechnik GmbH & Co.KG	Alphaliner	64	95.3	-	-
Van der Velden Rioleringsbeheer B.V. (NL)	iMPREG liner	41	95.1	89.3	↑
Aarsleff Rohrsanierung GmbH	PAA SF-liner	64	93.8	100	↓
GMB Rioleringstechnieken B.V. (NL)	iMPREG liner	27	92.6	-	-
TKT GmbH & Co. KG	Alphaliner	31	90.3	91.8	↓
Trasko a.s. (CZ)	Alphaliner	45	88.9	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner	102	87.3	92.9	↓
Aarsleff Rohrsanierung GmbH	iMPREG liner	96	75.0	94.1	↓
HF-Rohrtechnik GmbH (A)	Berolina liner	0	**	-	-
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	5	**	-	-
Swietelsky-Faber Kanalsanierung GmbH (A)	Brandenburger liner	0	**	-	-
UKDN Waterflow Ltd. (GB)	iMPREG liner	0	**	-	-
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	5	**	-	-

* 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

red to last year. Three other contractors managed to achieve 100% success rates for wall thickness, using the same type of liner. The bandwidth between the best result and the poorest is 25 %P for the test criterion of wall thickness and is thus conspicuous (see Table 4).

An examination of the various liner types shows that the test results for wall thickness fall into two groups: one group with a pass rate of 97% to 100%, and another group exhibiting poorer results, of 87% to 94% tests passed (see Table 6).

Tightness testing of CIPP liners

Table 5: Test results for water-tightness, 2015

Contractors	Liner systems	2015		2014	Trend
		No. of samples	Watertight in % of tests	Watertight in % of tests	
Arpe AG (CH)	Alphaliner	26		-	-
Arkil Inpipe GmbH	Berolina liner	155		98.8	↑
Geiger Kanaltechnik GmbH & Co.KG	Alphaliner	83		-	-
Geiger Kanaltechnik GmbH & Co.KG	Berolina liner	35		100	↔
Hamers Leidingtechniek B.V.(NL)	Alphaliner	104		100	↔
HF-Rohrtechnik GmbH (A)	Berolina liner	48		-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner*	93		79.8**	↑
ISS Kanal Services AG (CH)	Alphaliner	41		100	↔
Jeschke Umwelttechnik GmbH	Alphaliner	45		100	↔
Jeschke Umwelttechnik GmbH	Brandenburger liner	114	100.0	100	↔
KTF GmbH	iMPREG liner	90		100	↔
Pfaffinger Rohrnetz- & Sanierungstechnik GmbH	iMPREG liner	37		-	-
Kanaltechnik Agricola GmbH	iMPREG liner	39		100	↔
Sanierungstechnik Dommel GmbH	Alphaliner	43		-	-
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	29		-	-
Swietelsky-Faber Kanalsanierung GmbH (A)	Brandenburger liner	25		-	-
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	54		-	-
Trasko a.s. (CZ)	Alphaliner	45		-	-
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	56		-	-
Umwelttechnik und Wasserbau GmbH	Alphaliner	161	99.4	97.8	↑
Aarsleff Rohrsanierung GmbH	PAA SF liner*	114	99.1	100	↓
Average			**98.6**	**96.6**	↑
Erles Umweltservice GmbH	iMPREG liner	46	97.8	89.3	↑
Van der Velden Rioleringsbeheer B.V. (NL)	iMPREG liner	41	97.6	96.8	↑
Arkil Inpipe GmbH	SAERTEX liner	65	96.9	-	-
TKT GmbH & Co. KG	Alphaliner	249	96.8	98.5	↓
Aarsleff Rohrsanierung GmbH	iMPREG liner	178	96.6	97.2	↓
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	43	95.3	-	-
GMB Rioleringstechnieken B.V. (NL)	iMPREG liner	36	91.7	-	-
UKDN Waterflow Ltd. (GB)	iMPREG liner	27	85.2	-	-

* No cutting of integrated inner film | ** No cutting of integrated inner film since 15 September 2014, due to KOMO Foundation certificate in NL

– Not evaluated, too few liner samples

Water-tightness better

The test for water-tightness is passed on average in a pleasing 98.6% of all cases, an increase of 2.0%P compared to the previous year. Here, too, the overwhelming majority of the contractors have managed to maintain or improve their 2014 results. Poorer scores than last year are achieved only in three cases. The great improvement achieved by a Dutch contractor - by a good 20%P - is striking. This is attributable to an amendment to the approval (the so-called KOMO Foundation certificate) in September 2014, under which the inner film is to be considered an integral component of the liner. This film has since then not been cut prior to the water-tightness test.

Rehabilitation quality at high level in 2015

The quality of installed CIPP liners has nothing to be ashamed of: Anyone who awarded a CIPP liner rehabilitation project in 2015 could rightly expect that the specified targets for three of the four test criteria, i.e., modulus of elasticity, flexural strength and water-tightness, would be met with a probability of 98% to 99%.

This is without doubt an impressive statistic, one which is of comfort for project clients, and one which shows that the rehabilitation contractors and liner producers have significantly improved the quality of their services and products over recent years.

Quality also good outside Germany

For some good time now, more and more results obtained from foreign site samples have been incorporated into the IKT LinerReport. Conspicuous here is the fact that, with a few exceptions, liner types supplied by German producers are mainly used abroad, too, and that the installation quality closely approaches that of the German rehabilitation contractors.

With only a few exceptions, foreign contractors were well able to hold their own against their German counterparts in the 2015 LinerReport.

Table 6: Test results by liner types, 2015

Liner system	Liner type	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	292	100	293	100	293	100	126	100
Alphaliner	GRP	869	98.7	870	99.2	870	99.7	460	97.0
Brandenburger liner	GRP	195	100	193	99.0	193	99.5	114	100
PAA SF liner	NF	114	99.1**	114	99.1	114	97.4	64	93.8
Insituform CIPP liner	NF	93	100**	106	95.3	106	97.2	102	87.3
iMPREG liner	GRP	494	97.0	504	99.8	504	99.2	374	92.2
SAERTEX liner	GRP	65	96.9	64	95.3	64	98.4	56	100
Average			**98.6**		**99.1**		**99.3**		**95.4**

average or above average

below average

* Target values in acc. with client's data (structural analysis/sample data record)

** No cutting of integrated inner film

GRP: Glass-fibre backing material

NF: Needle-felt backing material

Table 7: Test results compared to previous year

Liner type	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		
	2015	2014	+/–	2015	2014	+/–	2015	2014	+/–	2015	2014	+/–
Average												
of all samples	98.6	96.6	+2.0 ↑	99.1	98.7	+0.4 ↑	99.3	98.7	+0.6 ↑	95.4	96.8	-1.4 ↓
GRP	98.5	98.7	-0.2 ↓	99.3	99.2	+0.1 ↑	99.5	99.5	+0.0 ↔	96.2	97.3	-1.1 ↓
NF	99.5	87.4	+12.1 ↑	97.3	96.2	+1.1 ↑	97.3	95.3	+2.0 ↑	89.8	95.0	-5.2 ↓

GRP: Glass-fibre backing material

NF: Needle-felt backing material

* Target values in acc. with client's data (structural analysis/sample data record)

Still keeping an eye on wall thickness

Only one small tinge of disappointment clouds the overall positive picture: the targets were achieved for the stability criterion of wall thickness in around 95% of all cases - but in 5% they were not. This means that the required wall thickness was not met in around every twentieth CIPP liner installation in 2015. The picture is much better for the other three test criteria, on the other hand. The test for water-tightness was not passed only in every seventieth installation, for example, that for modulus of elasticity only in every 110th and that of flexural strength only in every 140th.

Testing recommendable at end-of-warranty inspection

Clients should therefore emphatically insist on adherence to the contractual obligations, particularly in the case of the criterion most frequently not fulfilled, wall thickness.

Even if the test results after installation fall only slightly below the specified targets, renewed testing at the end-of-warranty inspection - i.e., after several years of exposure to operating loads - is nonetheless recommendable in every case.

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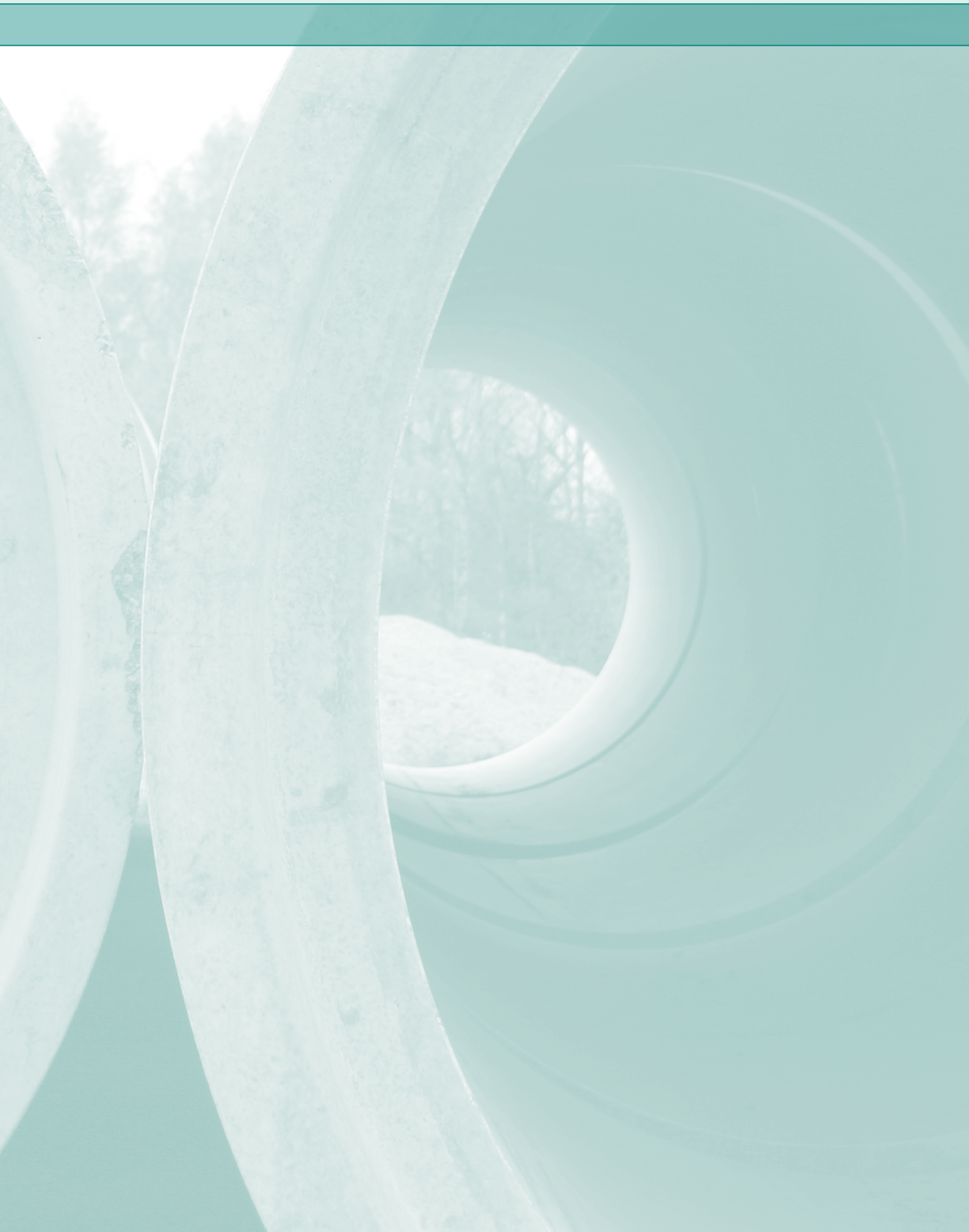


Stability of Manholes - a new application for the MAC System?

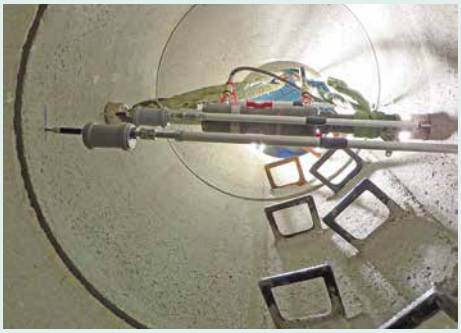
The MAC system has been further developed by IKT for semi-automatic deployment in pipes above DN 1000.

The MAC system has been designed to non-destructively assess the stability of man-entry, horizontally laid pipes. However, IKT has been considering whether this system could also be used in vertical situations? So, our developer team is examining whether it can also be used in manholes. Initial tests have already been carried out and the results show it works.

The large pipes under our streets are the 'autobahns' of the sewage system. They are in operation 24 hours a day, so everything must flow continuously. Consequently, expensive and wide-ranging repairs or replacements of pipes are usually put off for as long as possible. Therefore, the MAC system (Mechanical Assessment of Conduits) was developed to determine how a pipe needs to be overhauled so that it can remain in operation for many more years. Its measurements allow inferences to be made about the status of the pipe-soil system and to indicate suitable upgrading measures.

However, many millions of manholes are also connected with sewer networks. These are also subject to ageing processes and do not hold up forever. Can manhole constructions be checked in the same way and using the same methods as horizontally-laid pipes? IKT is currently looking into this question.

Of course a manhole should not to be equated with a wastewater pipe. In particular, completely different loads occur. However, the test principle remains the same: with its strong pressure cylinders, the MAC system can press the manhole wall outwards. This sounds more like the use of brute force than it actually is. Certainly, very high forces are sometimes applied, but the deformation required for the measurement is only a few tenths of a millimetre. Consequently the test does not cause any damage to the manhole as only sufficient force is applied to achieve this minimum deformation. Currently IKT is examining how the MAC system can be employed in manholes, how the measurements can be determined and whether the measurement data is usable.



IKT researchers use the measurements from the MAC system to determine the status of a manhole and the bedding ballast.

Normal deployment of the MAC system

It has been a long road to the point where the MAC system can be considered for use in manholes. However, this does not mean that the MAC device has the time to rest. It has been in routine use for testing pipes since the spring of 2015, following a long period of development and an intensive testing phase. The overall stiffness values of pipe-soil systems have been reliably determined in varied pipe situations in several German cities. The IKT MAC team is well experienced and trained for the job. Thanks to the 'tool-free' assembly and dismantling of its compact modules, the installation and recovery of the device on site is rapid. This provides more time for taking measurements during a deployment.

The modular construction of the MAC System means it can be lowered into a manhole in several parts and assembled below without using tools.

IKT is developing the MAC system further

The MAC system was invented by Eau de Paris, the water supplier to the French capital, and has been further developed by IKT. With the aid of this system, appropriate upgrading strategies can be prepared. Its use offers advantages, not only for the stability evaluation of large diameter pipes and manholes, but also for the quality control of completed upgrading work.

In France, the MAC system has been successfully employed since 1989 in large diameter pipes above DN 1500. IKT has adapted the system, in close cooperation with Eau de Paris, for employment in smaller pipe diameters above DN 1000 and has further developed the measurement and control engineering for semi-automatic operation.

Meanwhile, the Paris water supplier has ordered its own model of the more advanced MAC system from IKT. This is currently in construction and should be supplied to the cooperation partner shortly. IKT will train the team in Paris in the handling of the new MAC system and will accompany them during operational commissioning.

How the MAC system functions

Regardless of whether it involves a pipe or a manhole, the functioning of the MAC system is very similar in both situations. The MAC system has a powerful pressure cylinder which presses simultaneously against opposite walls of the pipe in a controlled manner, to move them apart from each other by a few tenths of a millimetre. Fine sensors measure the deformation arising in the area of the pressure plates and at a distance of approximately a metre in front and behind these points. The very small deformation that results is sufficient to calculate the status of pipe and surrounding soil, from a combination of the deformation detected and the force applied. The pipe is not damaged by the minimum deformation, despite the high forces applied, as automatic control of the pressure cylinder prevents any overloading of the pipe.

The measurements that are generated allow the stability of the pipe-soil system to be determined. Weak points can be quickly identified and further detailed information then derived through drilling cores and subsequent finite-element analysis.

Quantifying stability risks

After wall thickness values and strength properties have been determined through drilling cores, a static verification can be undertaken according to DWA A 143-2. If this verification is not sufficient, three-dimensional calculations according to the finite-element method (FEM) can be undertaken, which allow inferences to be made about the pipe and bedding ballast condition. On the basis of these calculations, it is possible to locate weak points in the pipe wall and loose zones or hollow spaces in the bedding ballast beyond.

Objectives for stability assessments

There are a range of objectives concerning the identification and elimination of stability problems that the MAC system can assist in meeting.

Finding the weak point - with the MAC system

In case of one survey in a German city, the IKT team did not expect any particular difficulties following the first inspection of a circular brickwork pipe. However, the MAC system indicated stability values which were completely unexpected and alarming. The problem was quickly identified during subsequent drilling core investigations, which found that the inner of three layers of brickwork comprising the pipe no longer had any connection with the external layers. This

The MAC system sees more than the naked eye. In this pipe it indicated some alarming values - the inner brickwork had detached from the surrounding brickwork.

was far less dramatic than initially feared, but could not be identified by eye. Further investigations are ongoing to provide a basis for decisions on suitable remedial measures.

In a medium-sized city in North-Rhine Westphalia, the MAC system helped in finding the correct positions for drilling core extractions in a brickwork profile. In this case the stability of the pipe-soil system could be subdivided into zones of similar stiffness from which targeted drilling cores were taken. With the MAC system the selection of drilling core sites longer needs to be

With the aid of the MAC system the correct positions for drilling core extractions can be determined in unusual profiles.

undertaken randomly, improving the information coring can provide.

Identifying the repair system - with the MAC system

The results of the measurements with the MAC system, in combination with the FEM calculations, give indications as to whether problems should be looked for in the bedding ballast or in the pipe. Assumptions can then be verified by means of drilling cores. Based on the results of an initial optical inspection, the first MAC test and the drilling core investigations, the objectives for remedial action can be determined. The entire pipe-soil support system can be divided into different upgrading zones. Specific objectives can be set for each, for example sealing, hydraulics or substrate improvement.

That then determines selection of the upgrading procedure, targeted at the weak points. For example, air-placed concrete linings for the static upgrading of the pipe or ground injections for the improvement of the bedding ballast. So, process selection not just based on an optical evaluation from inside the pipe and drilling of random cores. The stability evaluations provided by the MAC system are far more detailed and considerably more reliable.

Furthermore, considerable financial advantages can result. If, with the aid of the MAC system, it is possible to locally define a weak point, then any intervention can also be localised. Thus it is not necessary to upgrade the whole support system, as a precaution, simply because the precise location of damage is not known. Once the weak points are identified, they can be eliminated with targeted measures.

There are further applications that the MAC system can be used for on completion of upgrading work.

Checking the success of repairs - with the MAC system

Following upgrading work in a capital city on brickwork and egg-shaped pipe sections, there was a need to determine whether the work was successful. Therefore, a before-after comparison was made by the IKT team running through twice with the MAC system - once before the upgrading and once after. The measured values confirmed that the upgrade had achieved a significant improvement in the stiffness of the pipe.

This deployment showed that the MAC system is well suited to the quality assurance of upgrading work or to repeat control-checks of statically critical areas. Direct before-after comparisons

In this deployment space was confined, but the operators could still fit into the pipe.

and also time-related changes can be technically measured. Thus, the effectiveness of upgrading measures, such as ground injections or air-placed concrete linings, can be determined using the MAC system.

Verifying the long-term effect - with the MAC system

In addition to determining whether upgrading work has initially succeeded the MAC system can also be used to determine how long the effect lasts. By repeating MAC tests at stipulated intervals, comparisons of performance can be made over the long-term.

Ensuring quality of new construction - with the MAC system

The MAC system can even be used on new pipeline construction. With its assistance, the

The MAC system applies pressure on the pipe walls with its powerful hydraulic cylinder. The force required and the deformation are measured.

installation and bedding ballast relationships can be checked. Special advantage: As the planned boundary conditions are already known, „set point values" can be stipulated for later testing when the new construction is in operation.

Ensuring quality in production - with the MAC system?

And what of future developments? Having determined that the MAC system can be effectively employed for quality assurance after upgrading and with new pipeline construction, the possibility exists for using it to test new pipes in the factory. Its employment for the quality assurance of concrete pipes appears conceivable. Here considerable costs could be saved in the testing of large pipes, if the testing of the pipes from inside enables reliable statements to be made about the concrete quality and the reinforcement. Initial investigations of this application that have been carried out this year by IKT are promising. Here our developers see a still untapped potential for the MAC system.

Expenditure and costs in outlook

Finally there is the question of the cost of deploying the MAC system and undertaking the subsequent FEM calculations.

MAC System test costs

If the results of an existing visual inspection are available, IKT analyses these to determine the programme for the MAC test. It then agrees with the client the locations of the sections of pipe to be examined, together with the measurement intervals needed for each section. On the day before the test, it is recommended that the measurement points are identified and marked in the pipe. On the day of the test itself, the MAC system is assembled within the pipe and the measurements can begin.

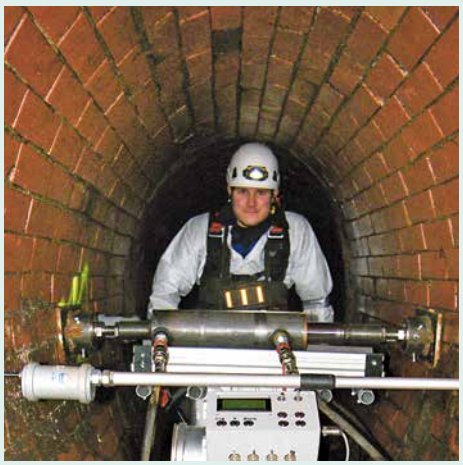
The installation and dismantling of the MAC system each take approximately 1.5 hours. With a measurement interval of every 10 m, about 100 to 200 m can be surveyed per day. Where feasible, the MAC system can be left in the pipe overnight in order to save on dismantling and setup times, thus increasing the daily survey performance.

Experience from tests on pipes of about 1,000 metres length indicates that the costs are approximately 10 to 15 Euro/m on average, for the first MAC test. The costs per pipe meter are particularly dependent on the investigation intervals which determine how many measurements need to be taken. Other factors that affect the price are the size and the structural status of the pipe, the access via manholes, the time that is available for working on site and the water level during testing. It is possible to use the MAC system up to a maximum water depth of 40 cm.

These prices do not include the costs of traffic safety measures, the guarantee of safe access to the conduit (cleaning, shut-off, ventilation etc.) and the drilling core extraction.

Costs of calculations of stability characteristics

On the basis of the test results, planning documentation and drilling core investigations,



Regardless of whether it involves a circular or oval section, a mouth or box - the MAC system can be employed everywhere.

calculations of the stability of each pipe section are undertaken using FEM to identify the weak points (in pipe or bedding) and to determine ground stiffness according to the applicable specifications. Experience indicates that these costs are approximately 8 to 10 Euro/m for 1,000 metre sections of similar cross-section and material type.

This rough overview illustrates clearly that the costs of a MAC test, including the static calculations, are below the annual costs for large pipes using the replacement value approach. With assumed building costs of approximately 1,500 Euro/m and a depreciation over fifty years, the annual cost is 30 Euro/m. The MAC test of a 1,000 m long pipe/soil system and the subsequent calculations together represent a one-off cost of approximately 18 to 25 Euro/m.

Identifying advantages

In comparison with conventional survey methods, far more information about the pipe-soil system can be acquired with the MAC system, without increasing the number of cores taken from a pipe or the surrounding soil. This is because more detailed, targeted investigations relating to the quality and geometry of the pipe

Profile? Material? Nominal diameter? Between DN 1000 and DN 3000, the MAC system can operate in all pipes.

can be undertaken. Furthermore, static calculations about the load distribution between ground and pipe can be implemented on the basis of the measured data and the results of drilling core. In this way, upgrading measures can be aligned to specific weak points. The selection of remedial procedures is therefore based on a more sound foundation.

In addition, the MAC system can be employed for the quality assurance of completed upgrading works through before-after comparisons or for repeat control checks of statically critical areas. In addition it can be used for checking of the pipe installation and ballast relationships in new pipeline construction. Perhaps, in future, the MAC system can also be used to assess manholes and new pipe production in the factory. The costs for such deployments of the MAC system may justifiable given the value of the information that can be provided on static load-bearing capacity.

Extending service life

As has been indicated, not only pipes but also manholes can be examined with the MAC system. If the investigation of both can enable localised repairs to be made to weak points in the network, then the expensive replacement of a large waste water 'autobahn' can be postponed.

The authors are glad to remain available in case of any concrete questions relating to the MAC system, its employment in conduits, the calculations and proof of structural stability.

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Inspecting pressure sewer pipes: Potential, requirements and results

Pressure sewer pipes are well down a sewer operator's list of their favourite parts of the network. Because there are no inspection or maintenance ports. Because the precise location of the pipe is often not known. Because numerous bends obstruct the flow. They can be found in practically all drain and sewer networks, but their characteristics and their special design confront sewer network operators with a real challenge when it comes to inspection and condition surveying.

Legal provisions

Pressure sewer lines can be found in many sewer systems and are subject to the legal provisions concerning inspection and condition survey, as defined for example in German federal states' regulations for self-inspection and self-monitoring. Sewer network operators frequently find themselves facing special challenges in implementing the required inspection work. High points and low points with no valves complicate draining and venting. There is a danger of blockages of the gravity system if pump operation is interrupted, with the potential for back-ups and flooding.

Against this background, sewer network operators also report significant consequential risks, such as soil collapse, long-term operating restrictions, elevated operating costs and greater proneness to depositions within the pipe resulting in permanently reduced delivery volumes.

The first phase of an IKT research project "Inspection and condition-surveying of pressure sewer lines and culverts" found that life-cycle observation of pressure sewers is becoming ever more important. This research was commissioned by the environmental ministry of the German state of North Rhine-Westphalia and supported by a group of sewer network operators [1].

This article reports on key new knowledge gained during the second phase of this project, which was conducted by IKT jointly with more than twenty sewer network operators [2]. The main results provide sewer network operators and technology suppliers with better understanding of the requirements for inspection technologies, the performance of water tightness tests and the selection of rehabilitation methods for pressure sewer pipes. A qualitative risk model for prioritising pipe-specific inspection, which is already being used by operators, is also discussed.

Test deployments of inspection technologies

Wastewater pipes must be robust, stable, operationally reliable and watertight, and must remain so throughout their scheduled service-life. The development of suitable inspection methods must address these targets. Therefore, the existing technical options were first discussed in a workshop with manufacturers of inspection technologies for wastewater pipes and for other supply piping (oil, gas, water, industry, etc.). The issues examined included the civil-engineering boundary conditions, possibilities for pipe-jacking, the special requirements of standards and codes of practice, and the water-tightness test as an augmentation of the standard inspection.

The technology manufacturers and sewer network operators identified specific requirements for inspection technologies focusing on:

- Water-tightness
- Leak detection
- Detection of weak points (in the pipe wall)

Two inspection technologies were then investigated to determine the extent to which these

Manufacturers and sewer network operators discuss requirements for inspection technologies

requirements can be achieved. The majority of pressure sewer pipes consist of steel, cast iron, asbestos cement or plastic, and so the investigations concentrated on these pipe materials. The following inspection methods, which are suitable in principle for such materials, were used and the information they generated and their performance efficiency was analysed:

- Steel: sewer radar, eddy-current method (SloFec)
- Cast iron: eddy-current method (SloFec)
- Asbestos cement: sewer radar

Test measurements were performed on pipe samples and in-situ deployments of the inspection technologies were monitored and documented.

The use of sewer radar in asbestos-cement pipes proved to be highly promising in principle. The test results obtained were also confirmed by means of a pH test using phenolphthalein. Phenolphthalein was used in an IWW, Mülheim, research project, and initially served the purpose of control measurement. Wall-thickness losses and discontinuities in the material were detected by the sewer radar system.

In-situ deployment of sewer radar

The eddy-current method (SloFec) was used to determine the order of magnitude of defects/leaks in one steel and one cast-iron length of pipe. It proved possible to detect both sudden changes in wall thickness and flat-surfaced simulated points of corrosion attack in both steel and cast iron. For steel pipe, it was possible to

Eddy-current test (SloFec) in a pipe sample

determine with certainty both defect depths and their precise position within the pipe. In the case of cast iron, accurate location was possible, but defect depths of diameters of <6.5 mm were inadequately detected by the sensors used.

Water-tightness testing standards

The sewer radar and eddy-current method (SloFec) are, in principle, not suitable for use in plastic pipes. Consequently, hydraulic (water-pressure) tightness testing may be more appropriate for this type of conduit. In addition, water-tightness tests are included in the standard procedures required for on-site acceptance inspection of gravity and pressure wastewater pipes in accordance with DIN EN 1610 [3]. However, for pressure sewer pipes, this standard only draws attention to DIN EN 805, „Water Supply - Requirements for Systems and Components Outside Buildings" [4] or, in the 1997 edition, to the prEN 805 draft standard.

DIN 1671, „Pressure Sewerage Systems Outside Buildings" [5] also cites DIN EN 805 in conjunction with inspections prior to the commissioning of a pipeline. The inspection procedure outlined in DIN EN 805 is described in more detail in DVGW Code of Practice W 400-2, „Technical Rules for Water Distribution Systems (German: TRWV), Part 2: Construction and Inspection" [4]. There is, at present, no dedicated inspection procedure for existing buried pressure sewer lines.

Water-tightness testing in accordance with DIN EN 805 was found to constitute an very high labour and financial cost for the project's participating sewer network operators. Consequently, they could not provide any in-situ test sites during the course of the project. Therefore, a test pipe for water tightness tests was set up at IKT as an alternative.

Contractors

Four water-tightness testing contractors for the gravity and pressure sector were commissioned to perform testing on the test pipe. Their selection was based on market research (Internet, visits to trade fairs), with subsequent enquiries placed with more than ten companies who explicitly claimed to have capabilities in the field of tightness testing. The aims of this investigation were to comparatively determine whether:

- differences exist when testing is performed at differing pressures;
- test time plays any significant role;
- testing can be performed with air remaining in the pipe;
- water-tightness can be reliably determined by means of such a test;
- adaptation to the conditions encountered in pressure sewer lines is actually possible.

A 27 m long PE 100 SDR17 DN 150 nominal diameter pressure pipe was installed in IKT's outdoor site in an existing 30 m long sewer section of DN 2200 concrete pipes. The test pipe was constructed to simulate difficult geometric circumstances (bends, ascents, slopes) and designed in such a way that the high points and low points could be variably selected.

The four contractors each performed water tightness tests on the test pipe. However, IKT itself first conducted its own tests using the same test programme and its own measuring technology was used for this purpose. This focused on three configurations.

The first test started initially using Condition 1 in which an air pocket of 8.0% of the entire calculated capacity of 424.72 l was created in the bend in Section 2.

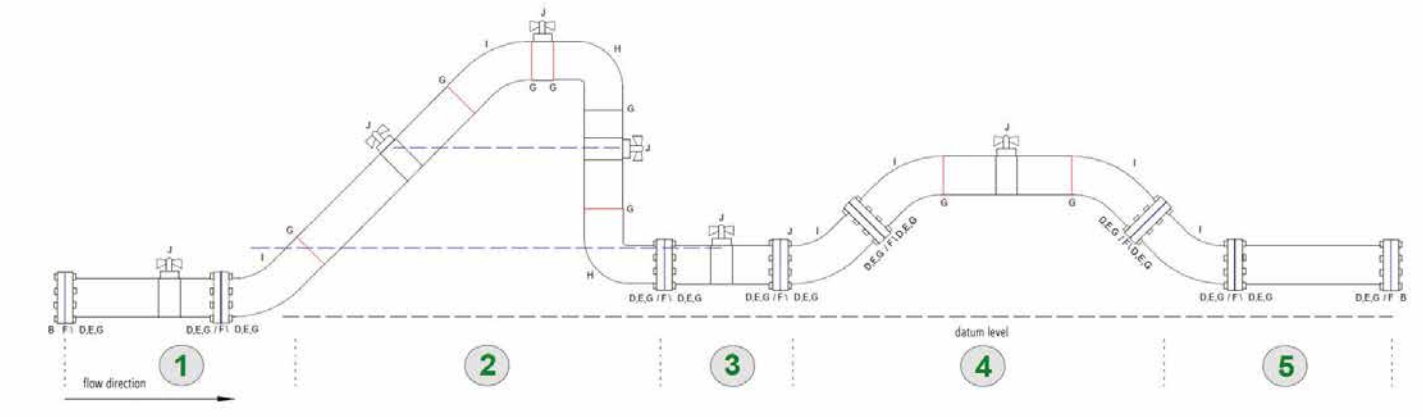
If no air was initially found in the test length by IKT or the contractor, the second test was conducted with an air pocket of 30.0% of total capacity (Condition 2).

Where the air pocket was found during the first test, the test length was completely filled with water in Condition 3 and then tested again.

Overall, the key questions were whether the contractors were aware of the individual process operations for water tightness testing and whether they were capable of applying them correctly. It was also intended to determine where there were any deficiencies and what limitations there were in performance.

Supplementary tests

IKT also performed supplementary tests on the sample pipe address other concerns expressed by the sewage network operators about water tightness tests on existing pipelines. In these the test criteria and boundary conditions were varied, and the results compared against one another. Questions on the extent to which limits can be determined and DIN EN 805/DVGW W



Test length of plastic pipe subdivided into sections with numbered valves

400, Part 2 test can be optimised, were also investigated. The following test criteria and test boundary conditions were selected:

- Water-tightness
- Magnitude and number of leaks (max. up to two leaks, each 55 µm)
- Variable test time (as per standard: 192 min.; 48 min.; 30 min.)
- Variable test pressures (8 bar; 6 bar; 5 bar; 4 bar))
- Air inclusions (no air; with 1.25% air; with 2.50% air)

The test time was the most important criterion for the sewer network operators. It is apparent, when examining the standards, that standard water-tightness tests can last for at least three hours. In fact, a test can take more than twelve hours in some cases, depending on the material. This long test period means that sewer network operators cannot easily interrupt operation for the necessary time. The consequence might be unacceptably large back-ups within the sewer system.

For this reason, a requirement was set that water-tightness tests should be completed within a relatively short time, in order to keep interruptions to operation to a minimum. Discussion with the sewer network operators concluded that 30 minutes was the target figure, signifying that the test time envisaged in DIN EN 805/DVGW W 400, Part 2 needed to be reduced to around a tenth of its original length.

The extensive tests performed demonstrated that it was possible to complete precise water-tightness tests in accordance with DIN EN 805 and DVGW W 400, Part 2 on IKT's test rig. The testing programme was able to investigate all of the test criteria and parameters selected to represent diverse situations in real sewer networks.

Knowledge gained

The detailed results of the investigations of water-tightness testing on pressure sewer lines are presented in greater detail in the concluding report for this research project [2]. The key conclusions can be summarised as follows:

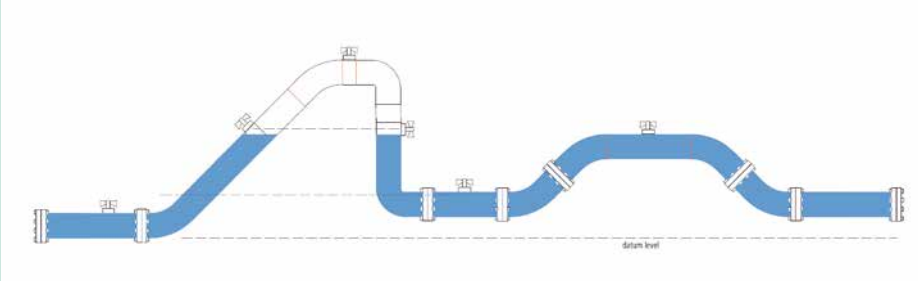
- It was ascertained during the tests performed by the contractors that three of the four contractors commissioned possessed inadequate knowledge concerning the performance of water-tightness tests on pressure sewer lines and concerning interpretation of the results.
- It was possible during the programme of testing to reduce the time needed for the performance of a water-tightness test to one tenth of the original requirement. The result nonetheless permitted assessment of the water tightness of the pipeline. However, the extent to which this can also be applied to other individual cases remains unknown at present.
- It is possible to identify leaks extremely quickly, assuming correct interpretation of the test results.
- Test pressure must not necessarily be greater than operating pressure in order to ascertain tightness. The tests showed that a conclusion concerning water-tightness can be drawn even at low pressure levels.

Qualitative risk management

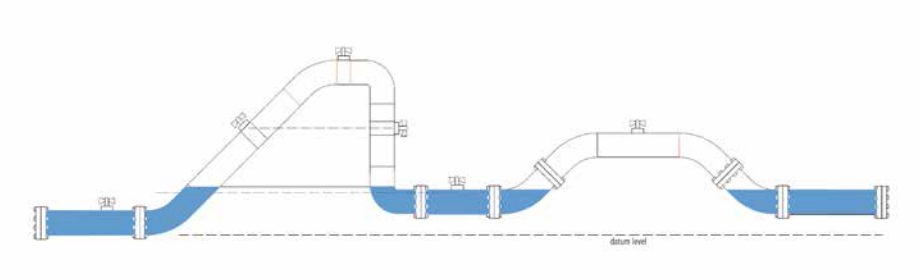
It is currently difficult to dependably assess installed pressure sewer pipes for their water-tightness, operational reliability and robustness, since inspections during operation are not usually considered at the design stage. Consequently, evaluation and management of the risk of failure confronts sewer network operators with significant challenges.

Therefore, IKT has developed a risk-analysis method for prioritising the most critical pipelines for a) possible further investigations and/or action, based on the probability of occurrence of failure, and b) for refurbishing of the pipeline based on the extent of damage. Thus, risks can be evaluated and controlled in such a way that the associated costs budgets can be systematically justified. A tried and proven procedure for this is risk evaluation of the probability of occurrence and the degree of damage involved, based on fixed evaluation data. Here, the same number of fixed risk values are assigned to both factors from which a risk index can be calculated, The significance of the relative values is shown in Table 1.

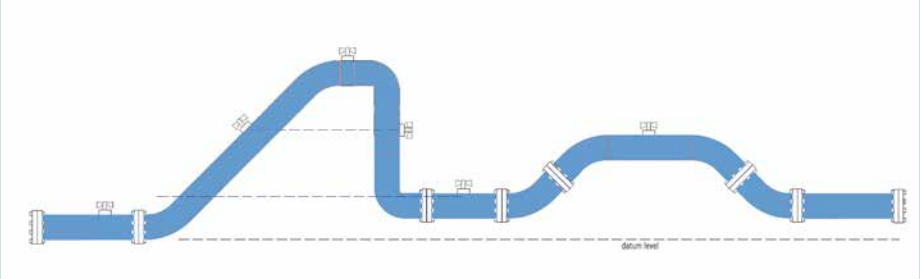
In an initial step, the possible risk factors for the respective operating network sector were determined and weighted (from 1 „Unimportant" to 5 „Extremely important") and the probabilities of occurrence of failure for each individual pipe were qualitatively estimated (again using a scale of 1 to 5 per risk factor) in a series of operator interviews conducted by means of questionnaires. The averages of the weighting of the risk



1. Bend in Section 2 half-filled with air



2. Bends in Section 2 and 4 filled with air



3. Test length completely bled and filled with water

Filling scenarios used in the test length of plastic pipe

A laptop records pressure data during water-tightness testing

Water-tightness testing equipment

IKT technology in use: a pressure sensor in the supply line

factors from all the questionnaires received are shown in Table 2.

In a normal case, several different approaches can be selected for determining extent of damage. For example, the extent of damage can be defined and determined in terms of its technical effects. The determination of technical rates of the extent of damage is generally extremely time consuming and is also not necessary undertaken in the context of a qualitative risk analysis.

Another possibility is determination of the extent of damage via economic factors. This was favoured by the participating sewer network operators, since the question of cost must be considered in all cases. Not only direct costs, but also indirect costs should be included in the analysis. The latter include costs which do not immediately affect the sewer network operator when a failure occurs. These include, for example, diversion of and safety provisions for traffic, the loss of road substance, damage to vegetation (lowering of the groundwater table, damage to roots) and also the additional burden on households/industry connected to the sewer, who must suffer restrictions for a period of time. These costs have, up to now, not been included in calculations, but nonetheless impose a long-term burden on the national economy [6].

Finally, and analogous to the remarks concerning risk criteria, criteria for describing the extent of damage were proposed and their weightings specified. This was undertaken by an internal discussion between the participating sewer network operators. Costs were in all cases considered to be the most important aspect by sewer network and were included in the evaluation with twice the importance (weighting: 2.0) of the other two criteria: the number of households/industrial enterprises connected and the environmental effects (weighting: 1.0 each). The sewer network operators that were consulted had the opportunity to definine/adjust the weighting at their own discretion (Table 3).

Once the individual weighting, the probability of occurrence and the extent of damage had been determined on the basis of the methods discussed above for all identified risks, they

PE 100 test rig, installed in 30 m long concrete pipe DN 2200

were entered in a risk portfolio. This is an instrument which provides an overview of the risk situation. Risk management was performed on this basis. The primary aim of risk management is that of achieving with the potential options available a „... reduction of the probability of occurrence (...) or a limitation of the effects of risks..." [7]. The drafting of a target risk portfolio is recommended, in order to assure the most efficient possible working procedure when assessing the Target/Actual condition.

Strategically important targets can be achieved for the pressure sewer network. A risk analysis of individual networks then permits classification of the various pressure lines within it. The network operator can decide at his or her own discretion which provisions, such as more extensive condition surveys or refurbishing projects, he or she wishes to deploy in order to reduce risk. Various classes of existing sewer can also be defined on the basis of the risk portfolio, enabling a network operator to manage the risks on a class basis. This risk model was implemented in cooperation with the municipalities of Burscheid, Bottrop and Gevelsberg.

Prospects

The inspection and condition-surveying of pressure sewer pipes continue to present special challenges to sewer network operators. The aim of this research project was to supply such operators with new knowledge concerning the operation and management of pressure sewer pipes. The focus was on the development of a risk model for pipeline-specific prioritisation of the need for action on inspection and refurbishing of critical pressure sewer lines. The risk evaluation enables sewer network operators to perform for themselves the assessment and management of existing risks.

The following areas were identified as requiring further work through optimisation or more extensive investigation:

- The available inspection technologies cannot, at present, be used for small-diameter pressure sewer pipes. Internal inspection of small pipes, which are found, in particular, in the private sector, is thus not yet possible.
- Among sewer network operators, there is in some cases lack of knowledge concerning the use of inspection methods. For this reason, sewer network operators should receive training, in order that they themselves, and also the private individuals advised by them (with respect to private pipes) are appropriately informed concerning the potential use of these inspection methods.

Table 1: Risk index for probability of failure and extent of damage observed

Risk index	Probability of occurrence	Extent of damage
1	Impossible[1]	Very low
2	Unlikely	Low
3	Possible	Moderate
4	Probable	High
5	Very probable	Very high

[1] This does not denote a scientific impossibility, but a qualitative abbreviation of the condition „in no way to be expected under normal conditions"

Table 2: Risk factors and weighting (averages of all questionnaires)

Risk factors	Weighting
Geometry/diameter of the pressure pipeline	2.57
Age of pressure pipeline	4.14
Location/depth of pressure pipeline	2.57
Installation/bedding errors	3.00
Technical pump aspects	3.29
Conveyed fluid	3.86
Materials properties	3.86
Soil properties	2.00

Table 3: Extent of damage factors and weightings

Damage-extent factors	Weighting
Costs	2.0
Number/importance of connected households	1.0
Environmental effects	1.0

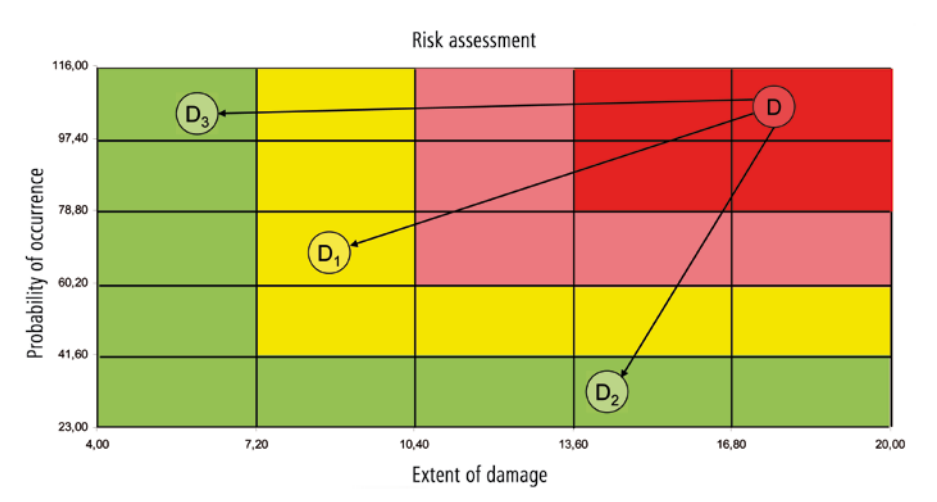
- Serious deficiencies were apparent in some cases in the performance of water-tightness tests by contractors. For this reason, sewer system operators and the contractors should be trained to improve their understanding of the results and in the correct performance of tightness tests on pressure sewer lines. Know-how in such fields as materials science/ building-materials technology, hydraulics, codes of practice, measuring technology and safety requires improvement.

- Shorter duration water tightness tests have the advantage that operation of a pipeline is interrupted only for a short time. For this reason, the development of shorter duration water tightness test should be investigated for other materials, such as steel, cast iron and concrete. Test sections should be constructed for this purpose, in order to evolve a procedure similar to that used for plastic pipelines. This would mean that water tightness tests would then be available for a major portion of existing pipes.
- Further investigations concerning risk analyses for existing pressure sewer lines are also necessary. In particular, the combination of prioritisation of the sewer pipes, lot formation and budgeting of further action is extremely important.
- Attention should also be devoted to sustainability aspects.

IKT workshop

The knowledge gained from this project has also been incorporated into the IKT „inspection, tightness testing and refurbishing of pressure sewer pipes" workshop. The workshop language is German.

- What are the important aspects for new sewer lines?
- How can testing of existing lines be performed?
- What is the right refurbishing procedure?



Target risk portfolio

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More than just water-tightness

Requirements for private site drainage systems

There are many water management and operational targets for wastewater systems which can be achieved only if private site drainage is included, as early as the conceptual planning stage concerning construction, operation and rehabilitation. This is legally supported by identical technical requirements for both private and public sewers in the German Water Management Act. Municipalities are therefore obliged to provide timely information and advice to site owners on both technical and legal requirements.

Neither legal nor technical codes of practice differentiate in principle between public and private sewers. This is true both of European requirements and their specific expression in national legislation [1-3]. What does this mean for site owners and for municipalities who bear responsibility for the disposal of wastewater? It is clear that more than just the water-tightness of the sewers is involved. The condition and functioning of the public and private network as a whole must be included and assured. Questions range from controlling the risk of blockages to the elimination of illegal connections, the prevention of infiltration and the avoidance of nuisance odours. Thus, it is clear that water management needs to start at the individual site.

Public and private sewers: Legal aspects

Across Europe, a watertight network of underground wastewater pipes and sewers assure the reliable collection and disposal of sewage and rainwater. The total length of public sewers within the European Union has been estimated at around 2.5 million kilometres [4]. No information is available on the total length of private site drainage pipes, since the focus is usually on public wastewater networks. However, wastewater disposal does start on the individual site, with the consequence that private site drainage networks must always be included when considering overall water management issues and the protection of soil and groundwater. This holistic approach is supported by legal requirements, technical codes of practice and standards.

The European directive concerning urban wastewater treatment (Directive 91/271/EEC) does not differentiate between private and public sewers, but instead refers to sewers as a piping system in which domestic, industrial and precipitation water is collected and conveyed. Annex I of this EC directive requires optimum technical knowledge for the design, construction and maintenance of the sewer system. It also clearly points out that leaks must be avoided. European standard DIN EN 752 [5] specifies targets for drainage systems located outside of buildings. Here, again, no differentiation is made between private wastewater pipes and public sewer systems. Four aims of drainage systems are defined very clearly in this standard: public health and safety, the health and safety of the workforce, environmental protection and sustainable development.

The German Water Management Act (WHG) [2] is no less demanding and specifies, in Article 60

Site drainage system in accordance with generally accepted standards of technology

of the current edition, that wastewater systems may be constructed, operated and maintained only in accordance with the generally accepted standards of technology. The drainage/sewer system is therefore to be observed as a whole, and no differentiation made between private site drainage pipes and public sewers. The WHG also states that the necessary action on any wastewater systems which do not conform to the requirements must be taken within appropriate periods of time.

The requirements of the federal Water Management Act are set out more specifically in the individual state water management acts. For example, The State Water Act in North Rhine-Westphalia (LWG) [3] states that the responsible authority is empowered to specify the nature, scope and frequency of inspections of wastewater systems. More detail is provided in the Self-Monitoring Ordinance Wastewater (SüwVOAbw) [6] issued by the state's Ministry for Climate Protection, Environment, Agriculture, Conservation and Consumer Protection. It defines not only the inspection intervals but also quality requirements for inspection.

More extensive requirements can be imposed in by-laws at municipal level. For example, The North Rhine-Westphalian State Water Act [3] empowers the municipality to set specific periods for the inspection of sewer laterals and/or site connections by means of by-laws. This option is useful when it is necessary to perform extensive rehabilitation work on the public sewer system in order to reduce infiltration. Here, private site drainage pipes must be included in the scope of work in order to achieve holistic water management. Only in this way can the overall aim of rehabilitation - i.e., a significant reduction in the volume of extraneous water treated - be achieved in such cases.

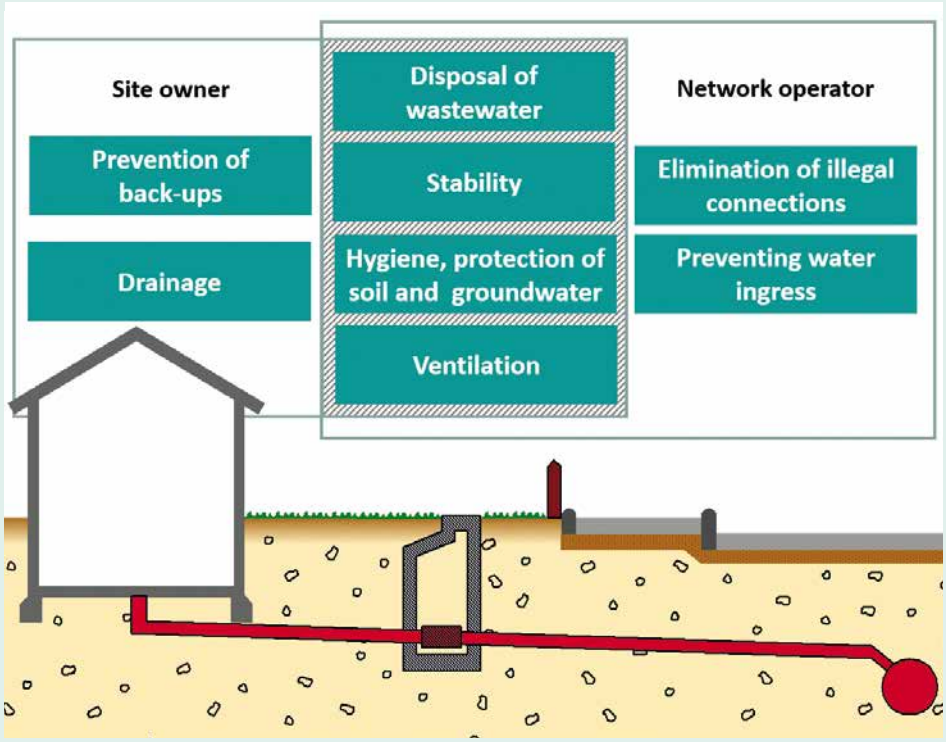
Requirements for the private site drainage system

The sewer system is in all cases regarded in the legal and technical provisions as a whole, i.e., both public and private sewers must be operated in accordance with the generally accepted standards of technology, and their condition and function surveyed at regular intervals and monitored accordingly. This is understandable from a technical viewpoint, since essential water management targets, such as assured hazard free disposal, can be only be achieved provided the entire system, consisting of public and private sewers and piping, remains operationally reliable, stable and watertight throughout its specified service life.

An examination of the many diverse requirements made on private site drainage systems makes it possible to differentiate between aspects which are of primary importance to the site owner and other aspects which are of greater interest to the municipal network operator. However, there are areas of overlapping common interest.

Non-aggressive cleaning methods must be used by the service provider when eliminating obstructions to flow (such as blockages and depositions) in private site drainage to avoid damage to the pipe [7].

In certain cases, there may also be a public responsibility for the elimination of obstructions to flow. A particular case is in public roads where the intrusion of roots from municipal trees or from roadside greenery into private sewer laterals may occur. In many cases, the owner of the tree bears co responsibility for eliminating root intrusion ([8], Article 1004 German Civil Code [9]).



Requirements for private site drainage systems

Disposal of wastewater

The availability and reliability of private site drainage systems must ensure the collection and removal of wastewater from a particular site. However, the correct functioning of private site drainage may be significantly impaired by obstructions to flow, damage, and/or installation errors. The site owner is responsible for ensuring that such problems are eliminated within an appropriate timescale.

Prevention of back-ups

For both economic and technical reasons, public sewer systems cannot be designed to immediately handle the volumes of water from every heavy rainfall event. Therefore, back-ups of sewage into the private sewer laterals/private site drainage pipes can occur for a short time when there are extreme burdens on the public drainage/sewer system. Back-ups can also occur if flow in the public sewer or in the private pipe is disrupted as a result of blockage. The site

Root intrusion into private sewer laterals

owner is responsible for ensuring that his or her building is protected against back-ups. If protection against back-up is lacking, the wastewater may be able to penetrate from the drain/sewer into the building, potentially causing serious damage and other problems [10].

Retrospective analysis of heavy rainfall events regularly shows that private sewers are, in many cases, not operating with any back-flow prevention. In inspections of twenty basements in Dortmund effective backflow prevention was lacking in all cases [11], whilst in Münster [12] no such safety features were in place in two thirds of some 150 sites examined.

Drainage systems

The long-term aim of municipalities is to eliminate surface water drainage system connections to sewers, whereas the overriding priority of site owners is to avoid damp in their buildings. The „Handling of drainage-system water from private sites - Pragmatic conceptual solutions and aids to argumentation" guideline [13] provides municipalities and system operators with useful notes on defusing this conflict of interests.

The discharge of groundwater and surface water into the public sewer system is prohibited in principle in the majority of municipal wastewater by-laws. Drainage system connections can, nonetheless, be found in virtually all municipalities. Estimates for North Rhine-Westphalia [14] assume that a drainage system is connected to the public sewer system for approximately 20 to 40% of all sites. These are systems designed for continuous drainage of plots of land. However, there are also drainage systems which were intended to only operate during the construction of buildings, that have not been disconnected from the public sewer system after completion of building work.

The result, particularly in zones with high groundwater tables, is a significant increase in the proportion of extraneous water in the public sewer system. The introduction of groundwater and surface water dilutes the wastewater, impairs treatment plant performance and endangers surface water if treatment plants and rainwater retention basins are overburdened. An increase in heavy rainfall events exacerbates the situation. In addition, the groundwater table may rise after refurbishment of public sewer systems resulting in further influx of drainage system water.

Stability

Severe damage to private site drainage pipes may endanger the stability of the pipe/soil system. This is true, in particular, in the case of Class A damage scenarios in accordance with DIN 1986-30 [15], such as „Cavity, or soil visible", „Infiltrating soil material", „Infiltration" or „Pipe fracture". Private wastewater pipes (such as sewer laterals) are also frequently located in the public road space. Hazard result from sagging and surface collapse, as was shown by an IKT survey of around seventy sewer system operators in North Rhine-Westphalia [16] during the „Concept for informing and involving citizens concerning private sewer laterals" research programme [17].

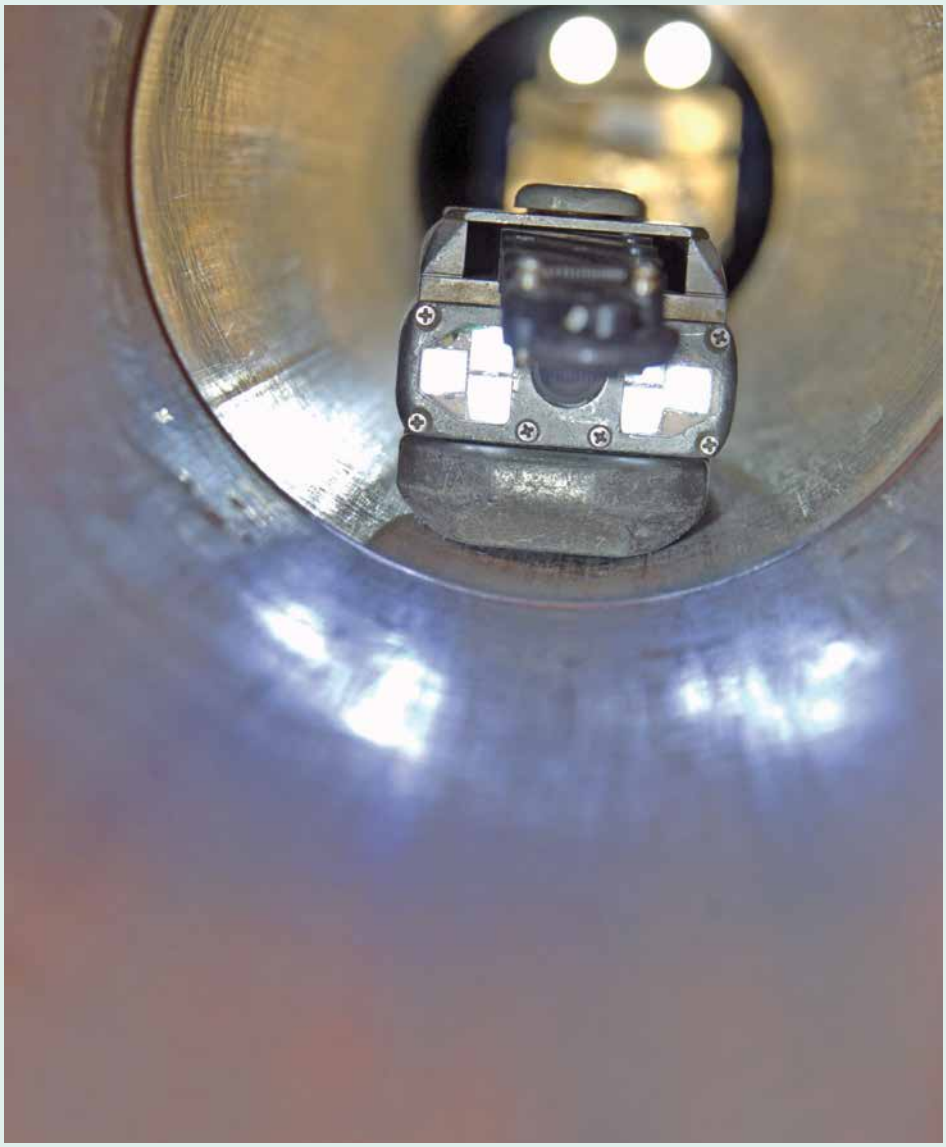
The site owner has an obligation to take action where damage which endangers stability occurs in private site drainage pipes. DIN 1986-30 [15] stipulates that immediate action must be initiated in circumstances that require it, on the basis of the principle of „cause for concern". Such circumstances include damage which causes danger of collapse, and consequently a threat to the safety of traffic and/or to the stability of nearby structures, traffic facilities or other amenities.

Hygiene and protection of soil/groundwater

Contaminated drinking water, including well water polluted with sewage, caused major cholera epidemics in London in the 1840s [18]. It was possible to systematically contain such epidemics only by constructing the London sewer system. Great importance therefore attaches to a correctly functioning and water tight sewer system, since damage to and/or leaks in sewage pipes and ducts can result in the escape of sewage into the soil and the groundwater [19–21]. The incidence of damage to public sewers in Germany is around 17% [22], while the incidence of defects in private site drainage pipes is estimated at around 70% [23]. Therefore, there is a particular need for action in the private sector on holistic sanitation provisions.

Ventilation

The air space in the sewer system serves as a volume and pressure equalisation space to assure the flow at different fill levels of a drainage



Condition and function of private sewers must be surveyed

system [24]. The movement of air also provides for air exchange and of the removal of moisture and gases from the sewage. A large number of openings assure the natural ventilation of drainage systems (see ATV-DVWK-M 154) [25]. These include, primarily, the roof vent of the private site drainage system connected to the public sewer system, in addition to the ventilation openings in the system's manhole covers.

Incorrect design and installation of the roof vent, that impairs or prevents air change and pressure equalisation, can result in odour nuisances [26].

The importance of correctly functioning ventilation for the sewer system was also documented in the IKT Comparative Test „Odour filters for wastewater manholes" [27]. For this cleaning performance (the odour-laden flow of waste-air) and air permeability, were selected as test criteria for manhole filters. Sewer system operators' practical experience demonstrated that greater corrosion [28, 29], attributable to inadequate air exchange, can occur in concrete manholes when odour filters are used.

Preventing water ingress

Groundwater can enter the sewer system via leaking private site drainage pipes and can cause various problems: impairing performance at the treatment plant, greater energy consumption at pumping stations and overflow at rainwater retention basins [30–32]. The consequences are significantly greater costs for wastewater treatment and disposal and impacts on surface-water quality.

Private site drainage lines must be included in extraneous water rehabilitation work on the sewer system in order to achieve a reduction in the ingress of water. If only the sewer network is sealed, there is a danger that more groundwater will enter the public sewer system via leaking private site drainage pipes and that the basic aim of reducing water ingress will not be achieved.

Elimination of illegal connections

Roof drainage systems and surface runoff from private sites on the site are frequently connected to the sewer system without permission. Such illegal connections increase the volume of extraneous water, with corresponding consequences for wastewater treatment/disposal, and for surface water quality (see „Preventing water ingress").

Overall, the large number of illegal connections can have significant effects on extraneous water volumes. During investigations of the town of Rheine's extraneous water burden [33] a smoke tracer was fed to all the private sites in the affected district to detect illegal connections. Illegal connections were discovered on approx. 6.5% of the sites investigated.

Support from the municipalities and the federal states

Against the background of the issues discussed above, the municipality comes under considerable pressure because of its obligation to dispose of wastewater. It can perform the tasks entrusted to it consistently, only if private site drainage is included. Numerous municipalities are already pursuing this route [33–36]. Extraneous water has, up to now, been the essential driving force behind developing holistic approaches to the influx of extraneous water. It affects the performance of public systems directly and solutions would appear to be very difficult without the inclusion of private site drainage systems.

Further examples of support from municipalities [37, 38] include the marketing and provision of municipal services to the private sector, such as condition and functional inspection of private site drainage systems.

The implementation of sanitary provisions frequently requires the involvement of citizens and/

or site owners. They require support, particularly with respect to the following:

- As-built plans and documentation obligation
  Under Article 61 (2) of the WHG [2], the operators of wastewater systems are obliged to monitor the condition and functioning of their systems, their maintenance and their operation, together with the content and quantity of the wastewater. A statutory instrument requires that records of this data be drafted, kept and submitted to the responsible authority upon request. In this respect, the WHG makes no differentiation between private and public wastewater systems, placing an obligation for both to maintain documentation. For private site drainage systems there is frequently inadequate documentation, even of the existing situation. In many cases, particularly old systems, pipe layouts are inadequately documented, if at all, and as-built plans are completely lacking [39].
- Consumer protection for „New systems"
  The generally accepted standards of technology apply, in accordance with Article 60 WHG [2], to the construction of wastewater facilities. However, errors in the planning, design and execution of new private site-drainage systems are common. To protect consumers, site owners need to be informed at an early stage about the potential risks - at the award of contract, and during performance of construction work. In addition, proof of quality criteria, such as a water-tightness test, should be required as part of the acceptance inspection of the works.

Municipalities can support citizens and/or site owners in the following ways:

- Information: to advise citizens on the issues and encourage involvement in joint (public/private) refurbishment projects.
- Advisory services: to provide more detailed information and in some cases feedback and observation, such as inspection of a site's drainage system and provision of advice.
- Technical services: construction, operation and rehabilitation involve many questions concerning condition surveying, evaluation and quality assurance. Quality assurance is always particularly difficult for citizens if the actual work takes place underground or is buried. Municipalities can provide specific advisory and information services on rehabilitation methods and quality assurance.

Where the environment and consumer affairs are the responsibility of the same ministry in a federal state (such as Bavaria and North-Rhine Westphalia), the issues described above may receive greater attention through special state regulations. It has been stipulated in Bavaria that only appropriately accredited persons are to be entrusted with inspections of wastewater facilities (see „Self-monitoring Ordinance" [EÜV] [40]). It also requires that technically qualified contractors (see specimen wastewater by-laws [41]) are employed specifically for work on private site drainage lines.

It is clearly stated in Article 53c of the State Water Act NRW, that the advisory obligation for implementation of the duties arising from WHG Article 60 and Article 61 [2] may also be funded from wastewater charges, as part of the wastewater disposal obligation. Municipal advisory services are supported by conceptual notes and PR materials [17]. In addition, the NRW Consumer Center has been integrated into the state's range of information services, in order to assure the availability of information for citizens throughout the state. The state of NRW has also regulated the approval of expert inspectors in the „Self-monitoring Ordinance: Wastewater" [6] to cover those technical services which, for citizens, largely take place „out of sight" (pipe inspections, in particular).

Conclusions

Water management starts on the site. Many water-management and operational aims can only be achieved if private site-drainage and its functions are included as early as the conceptual planning stage for construction, operation and refurbishment. This technical requirement is legally underpinned in the amendment to the Water Management Act and the formulation of identical requirements for private and public sewers in Articles 60 and 61 of the WHG [3]. The municipalities are, consequently, under pressure to inform and advise site owners in good time about the technical and legal requirements. Certain federal states have already taken consumer protection orientated action and are providing assistance in the form of regulations containing more specific detail and supporting provisions.

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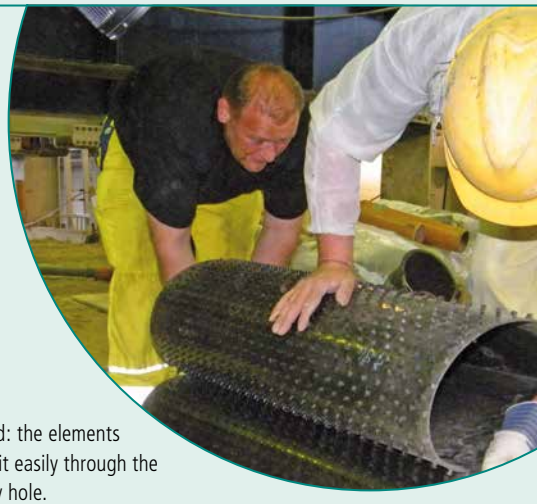
Testing assignment: IKT puts pressure on manhole lining



Cleverly folded: the elements of this lining fit easily through the manhole entry hole.

Leaks cannot be tolerated! So manholes in high water table areas must reliably keep any groundwater out. They need rehabilitating if they no longer do this. There are numerous methods to choose from.

Schacht + Trumme W. Schwarz GmbH, of Ahrensburg Germany, wanted to know whether their HDPE manhole lining would withstand continuous exposure to external water pressure, so they commissioned a test by IKT. The lining was installed into a systematically „pre-damaged" manhole structure consisting of prefabricated concrete elements in IKT's large-scale test facility.

Presence of groundwater simulated

The test programme, specially adapted for this particular case, included the following operations:

- Observation and documentation of installation of the manhole lining in a manhole shaft consisting of prefabricated concrete elements at IKT's large-scale test facility
- Application of external water pressure to the lining by means of two-stage flooding of the test facility (for a total of six months of water-pressure exposure of the lining)
- Visual inspection of the lining during exposure to external water pressure
- Checking of the bond strength of the lining/mortar back-fill with the manhole wall

The client's rehabilitating team installed the around 3 m high partial lining in the 5.5 m deep manhole shaft with no pre-sealing of the „implanted" points of damage. One day later, the large-scale test facility was flooded to a depth of two metres above the bottom sheet of the lining. This water level was kept constant for nearly four months, and then increased in increments to 4.5 m. This raised external water pressure was then maintained for another two months.

A giant sandpit: IKT's 6 m deep large-scale test facility can be flooded.

The joints between the individual elements are carefully sealed.

Leak tight to the end

IKT's test personnel inspected the lining at regular intervals for leaks and any other abnormalities. They found no leaks and no other abnormalities at any time during the test period or after the end of exposure to external water pressure. The connecting points of the newly installed climbing irons were also tight.

The bond strength of the PE lining and the grouting mortar with the wall of the manhole shaft was on average 0.4 N/mm² across various testing points.

The annular space between the manhole shaft and the lining is firstly grouted using mortar, and then sealed.

None of the tests carried out indicted in any impairment of the leak tightness and confirmed the suitability for use of this lining.

The overall verdict of IKT's test personnel was: PASSED.

The test report (German only) is available for free-of-charge to download at:
www.ikt.de/downloads/pruefberichte

IKT Comparative Test „Manhole Rehabilitation"

IKT's Comparative Test „Manhole Rehabilitation" has been undertaken at the large-scale test facility in Gelsenkirchen. Various rehabilitation methods, such as a range of coatings and linings, have been comparatively tested, under exposure to external water pressure, among other things. More about the Comparative Test and its results see page 5.

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IKT-tested: adapter ring makes old manholes HGV-proof

On test: Six different manhole variants, with and without compensation ring and with and without an adapter ring.

Sewer manholes in roads have a lot to put up with. They are exposed not only to vertical, but also to horizontal loads. For this reason, newer types of manhole cover are secured against lateral displacement. However, older types of manhole, with no such security, are still predominantly found in roads. For these, there is now an adapter ring available that is claimed to prevent displacement. IKT has tested this new solution.

HGVs: a burden on manholes

Vehicles passing over manhole shafts exert vertical loads on the structure. However, powerful horizontal forces are also generated if a heavy goods vehicle (HGV) brakes in front of or on the manhole cover. Horizontal loads even act on the manhole when a vehicle simply passes by, due to spreading of the load.

For this reason, new types of manhole cover installed since 1990 are equipped with anti-displacement fixtures. However, such design provision is lacking in the older systems. Up to now, it has not been possible to implement the anti-displacement requirement for the manhole top area in DIN EN 1917 and DIN V 4034, Part 1 when such a manhole is rehabilitated.

Adapter ring: retrofitted for security against displacement

The AdapTEC adapter ring, which prevents horizontal shift in the manhole top area and is intended to absorb larger vertical loads, has been developed by zarmuTEC GmbH & Co. KG. The cast-iron adapter ring connects the old smooth-surfaced manhole cone (in accordance with DIN 4034, Part 2) to the newer compensation rings (in accordance with DIN V 4034, Part 1), or directly to the manhole-shaft frame – force-locked and secure against displacement. AdapTEC reliably absorbs the vertical and horizontal loads acting on the manhole structure and diverts them away, protecting the manhole.

This ring, which looks like a giant washer, is installed in a bed of mortar on the older-type manhole cone. New-type compensation rings with anti-displacement fittings can then be mounted on this, an important benefit since older-type compensation rings are not quality controlled. However, the frame of the manhole cover can also be positioned directly on to the adapter ring. The cast-iron ring features on its inner side an upward and downward projecting collar which is intended to prevent horizontal movement of the adjoining elements relative to each other.

The problem: the individual parts of an older-type manhole cover can move relative to each other with time.

The remedy: the AdapTEC adapter ring creates a stable connection between an old manhole cone with no anti-displacement securement and new-pattern compensation rings.

IKT test programme: tested comparatively

IKT has tested the functionality of this innovative adapter ring in comparative tests performed on manhole components with and without an adapter ring. Manhole structures – consisting of the manhole cone, compensation rings and manhole-shaft frame with lid – were exposed in their upper areas to vertical and horizontal loads, and the maximum absorbable forces were determined. For reference: the relevant codes of practice assume that a brake application by a heavy truck can exert a horizontal load of around 72 kN on a manhole cover.

Concrete, mortar and iron guinea pigs:
a total of twelve test samples were used.

The tests investigated two load situations. First a vertical dynamic load in conjunction with a horizontal braking load on the cover. A horizontal load was then applied to the first structural element above the manhole cone/above the adapter ring, in order to determine the anti-displacement fitting's maximum load-bearing capability.

Two manhole frame set-ups were used - directly on the manhole cone and on two installed compensation rings, in order to cover different installation situations. Arrangements with and without an adapter ring, and with and without anti-displacement securement were tested. Two tests were performed on each arrangement. The forces and consequent displacement distances were recorded.

Results

All the test set-ups passed the tests involving combined wheel and braking loads without suffering damage. The shear-load only tests then separated the wheat from the chaff. The arrangements incorporating anti-displacement fittings, and the test set-ups with a built-in adapter ring, in particular, performed better.

In the case of the system with no anti-displacement fitting, shear failure occurred on average at 55 kN with a directly mounted manhole frame and at around 80 kN when compensation rings with no anti-displacement fitting were used.
The newer-type system with anti-displacement fittings failed at an average of up to 90 kN with a directly mounted manhole frame. Here, the concrete edge provided as the anti-displacement fitting was broken out. When compensation rings with anti-displacement fittings were used, everything remained in place even at the maximum shear force applied of 132 kN.

Stable system with adapter ring

The system with the adapter ring performed convincingly, both with a directly mounted manhole frame and with the use of compensation rings for anti-displacement by absorbing the maximum shear force of 132 kN. The zarmuTEC adapter ring makes it possible to install, when refurbishing a manhole, a system which conforms to the requirements of current standards and codes of practice for anti-displacement fittings and also possesses reserves of performance above and beyond these requirements. Thus the service-life of the manhole structure and the refurbishing intervals are thus both prolonged. So, bring on your heavy trucks!

Prospects: load calculation

These IKT tests exposed the test samples to horizontal and vertical forces up to either the point of failure or up to the load limits of the test apparatus. Prof. Dr.-Ing. Martin Radenberg (Chair of the Institute of Road, Railway and Airfield Construction of the Ruhr University Bochum) intends to investigate in detail how temperature differences may affect the loads acting on manholes and what other processes, such as fatigue and superimposed loads have an influence. This will provide even better understanding of the manhole top system and the stresses occurring. The manufacturer is confident that the adapter-ring system will continue to perform well in further tests.

Download test report (German version only):
www.ikt.de/downloads/pruefberichte

AdapTEC website: zarmutec.de

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Flexiblity: either compensation rings with anti-displacement securement or...

…the frame of the manhole cover can be installed on the adapter ring.

Sewer construction and rehabilitation

Review of the IKT Practice Days, 2015

Inside, specialists stand in small groups, excitedly talking, intensive discussions are in progress at the exhibitors' stands while, outside, practical demonstrations pop and hiss. The IKT's 2015 Practice Days are in full swing.

Around two hundred wastewater experts attended IKT in Gelsenkirchen, Germany, for the 2015 „New Construction, Rehabilitation, Repair" Practice Days. Here they heard informative specialist papers on new developments in sewer construction and rehabilitation, and exchanged ideas and experience. Live demonstrations showcased a large range of technologies and methods.

IKT director Roland W. Waniek welcomes visitors to the IKT Practice Days.

Sewer construction and renewal

DIN EN 1610

What is new in the sewer-construction „Bible" – the DIN EN 1610 standard? . Karl-Heinz Flick (Dipl.-Ing) of the Fachverband Steinzeugindustrie association of vitrified clay manufacturers and Bert Bosseler (Prof. Dr.-Ing. habil,), Scientific Director of IKT, provided an overview of new criteria including water tightness test requirements. Looking to the future, Karl-Heinz Flick announced „an ISO standard is coming" and appealed for delegates to cooperate in the standardisation bodies.

Fundamental rules of sewer construction: Prof. Bert Bosseler explains DIN EN 1610

Liquid soil: preventing root infiltration

Roots intruding into sewers – something no one wants. This is why root-inhibiting liquid soils are enjoying ever greater popularity for backfilling of pipe trenches. Jana Simon (Dipl.-Ing.,) of the University of Kassel and Marcel Goerke (M.Sc), IKT project manager, explained the advantages of temporarily flowable, self-compacting backfill materials, and outlined where attention is needed in their use.

Jana Simon (Dipl.-Ing.) of the University of Kassel explains backfilling pipe trenches using liquid soil

Jana Simon also reported on a University of Kassel research project focussing on further optimisation of liquid soil. Marcel Goerke discussed IKT's plans for a „liquid soil" product test and called on network operators to participate in it, one aim being the drafting of specimen supplementary technical contract conditions.

Expansion of broadband coverage via sewers

The aim: High-speed Internet in even the most remote corners of countries. However, burying broadband cables across long distances is extremely expensive. So why not use existing infrastructures and install them in, for example, sewers? Frank Grauvogel (Dipl.-Ing.,) of the Burscheid municipal utilities and Dr. Sissis Kamarianakis of IKT spoke on the potential and risks of this method based on the experience gained in Burscheid and recent IKT studies. Their conclusion: interesting potential, but crucial questions remain to be answered.

Frank Grauvogel reports on experience in Burscheid on installing broadband in sewers

Certificates for the world's first IKT-certified sewer operation managers

The world's first IKT-certified sewer operation managers received their certificates during the Practice Days. All twelve candidates had passed the necessary examinations and nine were awarded at the event.

Proud graduates: the first IKT-certified sewer operation managers receive their certificates.

Live demonstrations: new sewer construction and current trends

Around midday, the participants and exhibitors were refreshed and reinvigorated with a tasty barbecue before the afternoon's „potentials market" and practical demonstrations. Numerous manufacturers showcased their technologies and methods live, and at eye level, on the IKT site. It was fascinating to see things usually hidden in a trench, and what happens in a sewer. The welding of a branch joint to a PE pipe, substrate preparation, use of a water-jet cutter prior to the rehabilitation of a manhole and the functional mechanism of a liquid-soil mixing system were among the attractions on show.

Practical demonstration: trimming off the projecting socket after welding a joint

Exhibitor interviews

Exhibitors who did not have technical demonstrations had the opportunity to showcase their companies, products and services to the visitors in short interviews. The IKT „film crew", Sebastian Beck (Dipl.-Ing.) and Dr. Sissis Kamarianakis, took a microphone and camera to exhibitors on their stands and these interviews were relayed directly to a large-format screen.

Lively debate: which material for which situation?

The live demonstrations were followed by the now almost traditional lively debate session „tough, but fair". This time on the controversial subject of „sewer construction; "which material for which situation?". There was intensive discussion between the advocates of various lines of thought on this subject: Dr. Ulrich Bohle (Steinzeug-Keramo GmbH), Manfred Fiedler (Göttingen Disposal Services/Fiedler Consult), Wilhelm Niederehe (FBS – Fachvereinigung Betonrohre und Stahlbetonrohre e.V.), Jürgen Rammelsberg (Fachgemeinschaft Guss-Rohrsysteme (FGR) e.V.), Andreas Redmann (KRV – Kunststoffrohrverband e.V.) and Dr. Claus Henning Rolfs (Düsseldorf municipal drainage services). Discussion focussed, among other things, on the durability of the various materials and their resistance to root damage at joints. IKT then invited all participants, speakers and exhibitors to join the evening programme of events. Here discussions continued in an informal atmosphere – as we don't, after all, see each other every day, so it's a good idea to take every opportunity to talk!

„Tough, but fair" debate – the issue of materials: intensive discussion between the advocates of various lines of thought

Sewer repairs

The papers on the second day focussed on sewer rehabilitation and repair.

Rehabilitation wastewater manholes

There is, on average, a manhole in the road every 40 m in the town of Hagen, a total of some 17,000, reported Vera Rabe (Dipl.-Ing.) of Hagen municipal services. All these manholes need maintenance, and rehabilitation when necessary. But which system is the right one for which particular case? Plastic, mortar or a lining? IKT's „Manhole Rehabilitation" comparative test deals with this question. Serdar Ulutaş, Dipl.-Ing. (FH), MBA, head of IKT Comparative Tests, reported on this work, which has since been completed, but was still very much ongoing at the time of the Practice Days.

Vera Rabe explains Hagen municipal services' experience of manhole rehabilitation

The test results have now been published (see the article in this issue on page 5). Conclusion: reliable manhole rehabilitation is possible using commercially available systems, even with subsequent exposure to groundwater pressure. Good test results proved to be a question less of the particular material than of the system used.

Rehabilitation of main sewers

Erik Laurentzen (Ing.) of the City of Arnhem and Dr. Götz Vollmann of Ruhr University Bochum focussed in their papers on risk analysis for a combined sewer, citing the case of the Moerriool, in Arnhem. The Moerriool is a 130-years-old main sewer and is of great importance for urban drainage in the city, but was in an extremely poor condition.

Dr. Götz Vollmann, Ruhr University Bochum

Potential risks involved in rehabilitation were first identified prior to any action being undertaken. These risks were then classified by their probability of occurrence and magnitude of damage. The result: the repair method that had been proposed was not viable over the long-term, so an alternative rehabilitation method is urgently needed, even if it results in greater costs.

Rehabilitation of sewer laterals

Sascha Köhler (M.Sc.) of the Herne municipal drainage department discussed the procedure used in the city for private site drainage system rehabilitation. During work on the collecting mains, the drainage department also inspects the connecting lines. This data is then evaluated and property owners are advised accordingly. This takes place around 800 times each year. Where rehabilitation is necessary, the owner can decide whether he or she will commission the necessary work, or entrust this to the municipal drainage department.

Sascha Köhler, municipal drainage department, Herne

Sebastian Beck (Dipl.-Ing.) of IKT provided additional general information on the legal basis, the predicted need for rehabilitation, and the various rehabilitation methods, including renewal. He also presented useful information compiled by IKT on behalf of the North-Rhine Westfalia environmental ministry for owners and wastewater management organisations.

Large technical exhibition

The participants used the breaks for their own discussions and to exchange experience. They were also drawn to the large technical exhibition, featuring twenty-five exhibitors from the industry. Details of technical innovations were explained to visitors, who also asked the stand personnel plenty of questions.

Make a note!
IKT Practice Days, 2016:
New construction, rehabilitation, repair
7-8 September 2016
www.ikt.de/seminare
IKT, Gelsenkirchen, Germany
Contact
Dipl.-Ing. Sebastian Beck

1st Dutch „Sewer Repair" Practice Day

Intensive discussions, practical presentations and technology in action – IKT Netherland's first Practice Day aroused the enthusiasm of both participants and exhibitors. Some 350 international guests, three quarters of whom were from municipal wastewater management organisations, attended the event in Harderwijk under extremely pleasant weather conditions. Around thirty exhibitors from the Netherlands and Germany demonstrated their products and methods through practical presentations.

Experiencing technology in action

The spacious setting of the Bouw & Infra Park in Harderwijk provided the exhibitors with scope to show their technologies, equipment and methods live to the participants. Inspection, milling/cutting and liner fitting were all popular attractions. And, above all, the weather was on our side!

Fascinating range of presentations

The technical papers were received with great interest by the participants. Dutch sewer network experts spoke on topics including inspection, tendering and guarantees, injection-grouting and manhole rehabilitation. The reports on actual experience by the municipalities were of particular interest.

Make a note!
2nd Dutch Sewer-system Practice Day
22 September 2016
Bouw & Infra Park, Harderwijk
www.ikt-nederland.nl

Contact
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IKT Nederland

Around thirty exhibitors showed their technologies, equipment and methods in action.

What does IKT do?

The IKT is a neutral, independent non-profit institution, and works on a practically and application-oriented basis on questions concerning underground sewer, pipe and other conduit engineering, its primary focus being on sewer systems. The institute conducts research projects, inspections, product tests, consultations and seminars on the construction, operation and renovation of underground infrastructures.

The IKT's main target group consists of the operators of both public and private conduit systems; its fields of activity are primarily oriented around questions and problems encountered by system operators, activities which derive from the institute's founding charter, signed in 1994, and stating its aims as the acquisition of scientifically founded expertise for the achievement of the cost-effective, technically innovative, and both environmentally and citizen-friendly installation, renovation and maintenance of conduit systems.

The IKT also performs other supporting activities in the field of testing and trial of new products and methods for industrial companies.

The fields of activity of the IKT are in details:

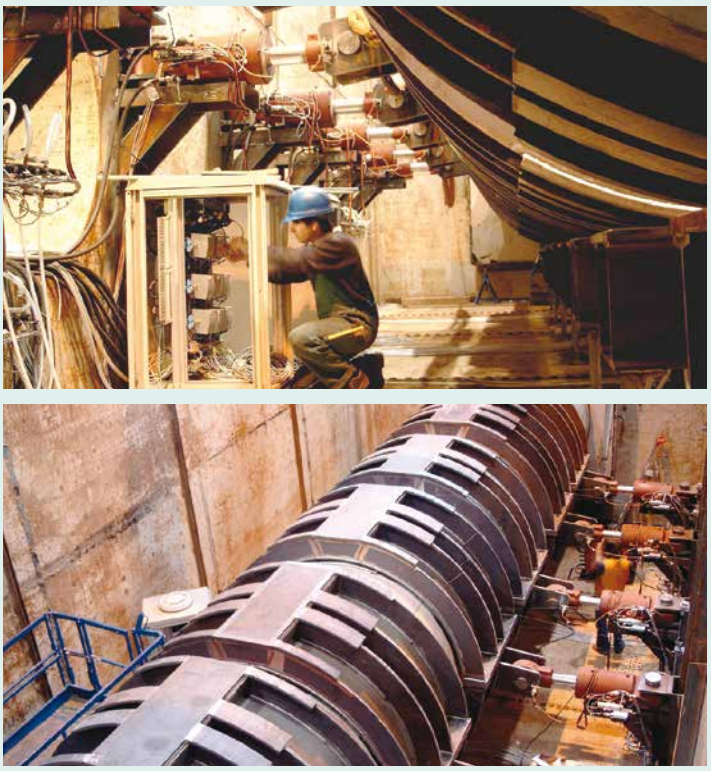
- Practice-oriented research
- Construction supervision, materials testing, flow measurement
- Comparative product tests
- Organisation of networks
- Further training
- Consultation and expert appraisals

Practice-oriented research

The IKT's application-related research focuses predominantly on the solution of system operators' problems and questions. The institute maintains continuous close contacts with the operators, in order to detect topics needing attention. The system operators' steering committees support and monitor all IKT research projects; members of these steering groups select the products to be tested and evaluated, determine boundary conditions for such tests, and are directly informed concerning the latest findings and developments at regular intervals.

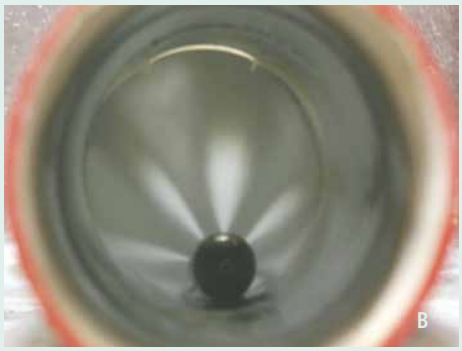
The first step in any IKT research project is a thorough analysis and definition of the problem.

Hydraulic cylinder in the IKT large scale test facility



IKT jacking simulator, DN 1600

IKT-Services



A View into a sewer manhole
B HP nozzle in sewer
C Root ingrowth into a sewer

Practical solutions are then drafted, and subsequently implemented at pilot sites or incorporated into instructions for action and recommendations for the system operators.

Research topics:

- Sewer operation
- Sewer cleaning
- Urban drainage
- Sewer renovation
- Sewer manholes
- Sewer construction
- Pipe-jacking
- Root ingrowth

Construction supervision, material testing, and flow measurement

The results of the IKT's research activities are incorporated via short routes into the institute's subsequent activities.

- Vertical compression test
- Flow measurement
- Adhesive pull test on a coated manhole

The IKT provides system operators with practical product and system tests for Quality Assurance purposes, construction supervision, comparative flow measurements at sewage treatment plants, storm-water tanks and reservoir channels, calibration of flow and control equipment, and also tests in accordance with the self-diagnosis ordinances of the federal German states.

Initial and suitability tests, standard materials tests, DIBt certification procedures, special individually co-ordinated tests, and also supporting tests for method development, can be performed for manufacturers.

These tests are performed by the IKT's three test centres:

The three IKT test centres

Test centre for construction products	Test centre for flow measurements	Test Centre for stormwater
Accredited in accordance with D-PL-18196-01-00 DIBt-accredited • Test, supervision and certification unit	**Nationally accredited** • in accordance with EKVO Hessen • in accordance with SüwV Kom NRW	**DIBt-designated**
Main focus • Materials tests (plastics, concrete, vitrified clay, tube liners) • Construction supervision • Quality Assurance (e.g. of sewer and manhole renovation projects) • Test institute for DIBt construction-supervision certification	**Main focus** • Comparative measurements at sewage treatment plants, storm-water tanks, reservoir channels • Calibration of flow-measurement and control instruments • Tests in accordance with SüwV-Kan and SüwV-Kom • Detection/quantification of extraneous water • Expert appraisals	**Main focus** • Testing of decentralised precipitation-water treatment facilities (DIBt) • Testing of waste-water treatment surfacings (DIBt) • Assessment of the comparability of performance of decentralised precipitation-water treatment facilities in North Rhine-Westphalia • Laboratory and in-situ evaluation of the permeability performance of permeable paving systems

Crown pressure test

Adhesive pull test on a coated manhole

Examination of stability

In addition, first and suitability tests, standard material tests, technical approval by the Deutsches Institut für Bautechnik (German Institute for Construction Technology, a government body, German abbreviation: DIBt), individually coordinated special tests, as well as supporting tests in procedure development can be carried out for product manufacturers.

Comparative product tests

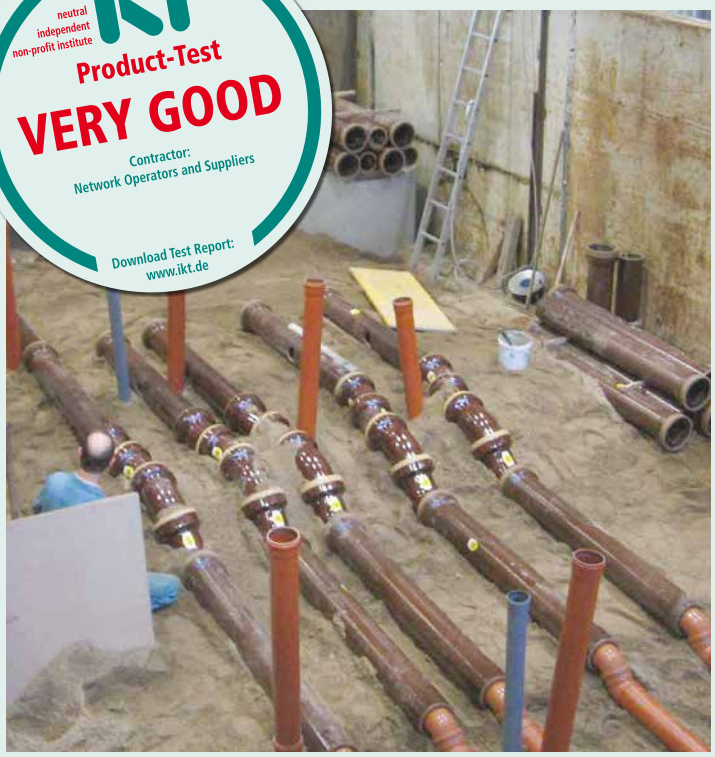
Comparative product tests, in which products and methods are intensively tested under both laboratory and practical conditions, are a particular IKT speciality. All product tests are conducted by a group of system operators. Decisions concerning test contents, procedures and criteria, and also the concluding assessment, are taken jointly by a group control committee, thus ensuring that these tests are performed on a practical basis, impartially, and without influence by commercial interests.

The test results supply sound and reliable information on the strengths and weaknesses of the products available on the market to system operators, enabling them to make purchasing decisions on the basis of facts, rather than manufacturers' advertising. The IKT's product tests also provide suppliers with criteria for the improvement of the products and procedures tested, and thus for enhancing their market position.

Organisation of networks

The IKT increasingly sees its role as that of providing a platform for networks. The "Municipal Network for Site Drainage" (KomNetGEW) has existed since as long ago as the summer of 2008. The principal concern of the around sixty-five member municipalities is "citizen-friendly" implementation of tightness testing in accordance with Article 61a LWG NRW. Materials for PR activities and advisory services for citizens are centrally drafted under the overall leadership of the IKT and provided for use by all participants. The KomNetGEW has, in addition, now also certified several hundred site drainage consultants and expert tightness inspectors.

System operators assess dismantled test objects



Construction of a pipeline system at the IKT large-scale test facility

Network members adopt common paths

IKT-Services

Training and further-training at the IKT

The "Sewer Operators Forum" within the IKT was founded in 2011 and provides all waste-water organisations with the opportunity for intensive interchange of experience. The results obtained in workshops, workgroups and research activities are structured and summarised by the IKT.

Further training

Over the years, the IKT has acquired a pleasing reputation as a training and further-training institution. Consultants certified in Gelsenkirchen are trained in site drainage at regular intervals. Expert tightness inspectors also obtain the necessary know-how here. The "Site Drainage Day", held by the IKT for the fifth time in 2014, has also become a permanent feature in the industry's events calendar. The "Conduit Cleaning Day" is also worth to note. The institute's further-training programme is rounded off by training events and courses on various topics of waste-water management, including manhole renovation, occupational health and safety, and photo reference catalogue.

Consultation and expert assessments

The IKT provides, on the basis of findings from research, inspection and testing activities, support services orientated around specific questions encountered by system operators (e.g. on-site analyses, feasibility studies, presentation and mediation, technical and economic assessments, economic and social cost analyses, etc.). The IKT's services also include thoroughly scientifically founded expert assessments for courts, municipal and private system operators, building contractors, product manufacturers and engineering consultancies (e.g. expert damage assessments, expert opinions as evidence in court and in out-of-court settlements). An overview of the IKT's specific consulting services in its various fields of activity is shown below:

IKT consulting services

- Sewer cleaning/operation

Day of practical sewer operation, checking of tendering, assessment of damage caused by sewer cleaning (e.g. flow back-ups, cellar flooding, etc.), cause analysis of cleaning damage to sewage conduits, malfunction analysis (drain blockages, clogging, etc.), assessment of cleaning strategies, recommendations for non-destructive sewer cleaning, drafting of market surveys, recommendations concerning the high-pressure flushing resistance of pipe products, organisation and presentation of system operators' regional interest groups, optimisation of reporting.

- New sewer construction

Trenchless ("no-dig") installation (pipe-jacking), open-trench installation (timbering supported, pipe-trenches), statics calculations (stability), core drilling and testing (materials testing), damage documentation and assessment, registration and evaluation of current construction methods.

- Manhole renovation

Selection of renovation procedures, Quality Assurance for renovation projects, registration and assessment of renovation quality, analysis and evaluation of renovation damage, practical suitability testing of renovation systems.

Sewer renovation
Quality Assurance for renovation projects, recommendations concerning use of modern materials in sewer renovation (and plastics, in particular), tube liners, part-liners and coating methods; analysis and inspection of renovation damage.

Urban drainage
Trenchless installation methods (renovation of connection points and pipes), open-trench installation (pipe installation, connection to main sewer systems), malfunctions (drain blockages, clogging, etc.), damage documentation and evaluation, registration and evaluation of actual condition.

Water-permeable surface coating
Seepage capacity, pollutant retention, drain performance, DIBt certification.

Root ingrowth into sewer systems
Tree identification using samples of ingrown roots, documentation and evaluation of cases of damage, recommendations for the removal of ingrown roots and for repair of damage.

Reporting and self-diagnosis ordinance
Consulting services on implementation of legal requirements (EKVO, SüwVKan), documentation and optimisation of structure and flow organisation, updating of servicing and operating instructions orientated around the relevant requirements, finalisation and systematisation of reporting, co-ordination with responsible supervisory authorities.

Flow analysis and comparative measurement
Review of measuring instruments for use at storm-water tanks and sewage treatment plants, on-site comparative measurements using ultra-modern measuring instruments calibrated at regular intervals, measurement of extraneous water flows, determination of extraneous water sources and causes.

Economic analyses
Cost:benefit analyses comparing trenchless and open-trench installation methods, evaluation of investment and rehabilitation strategies, economic evaluation of sewer systems and structure, cost-cutting and economic optimisation provisions, macro- and microeconomic analyses.

More information?
We are always pleased to answer your questions about our services - just contact us!

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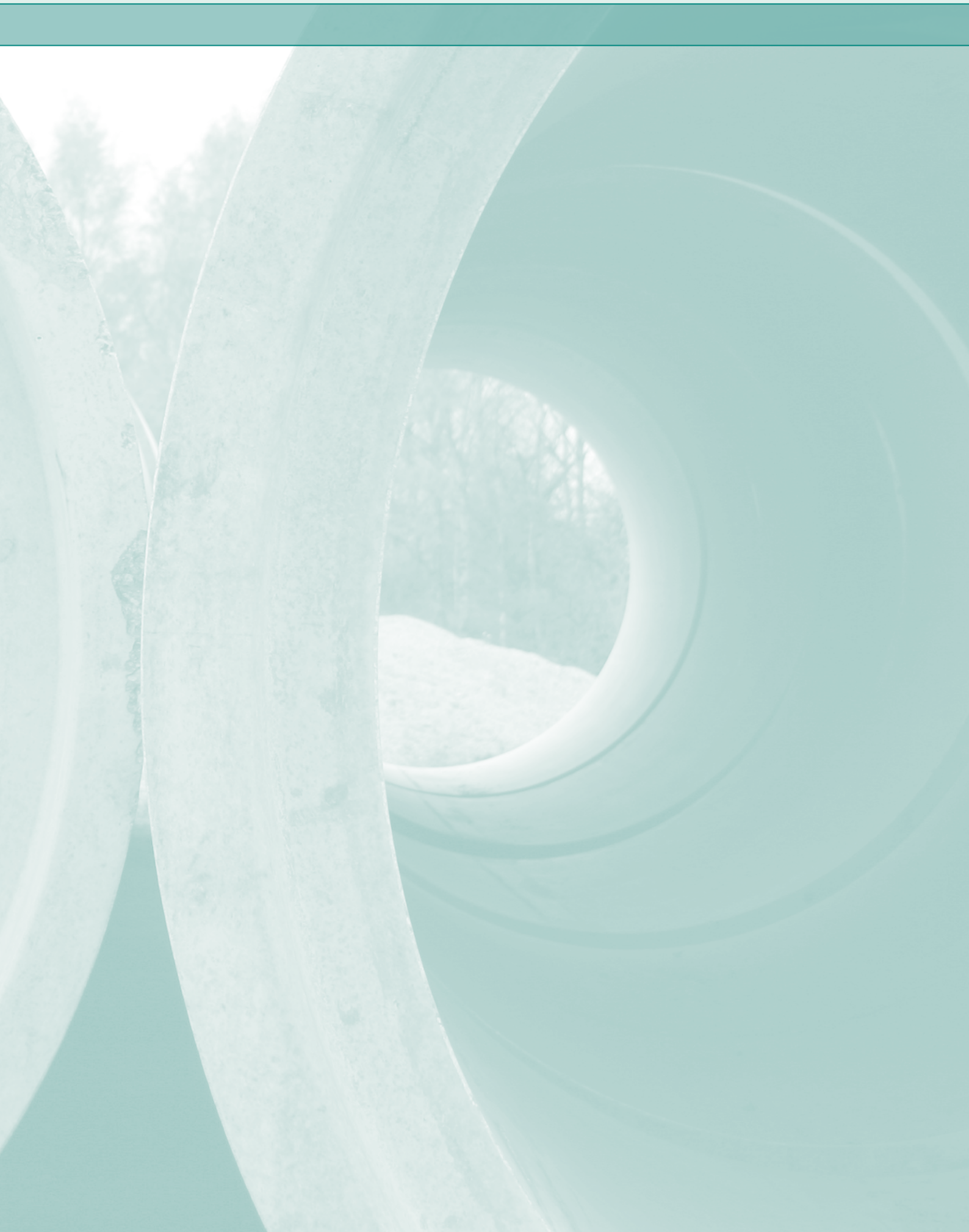

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neutral
independent
non-profit institute

IKT - Institute for Underground Infrastructure

ABOUT IKT

IKT - Institute for Underground Infrastructure is a research, consultancy and testing institute specialized in the field of sewers. It is neutral and independent and operates on a non-profit basis. It is oriented towards practical applications and works on issues surrounding underground pipe construction. Its key focus is centred on sewage systems. IKT provides scientifically backed analysis and advice.

IKT has been established in 1994 as a spin-off from Bochum University, Germany.

The initial funding for setting up the institute has been provided by the Ministry for the Environment of the State of North-Rhine Westphalia, Germany's largest federal state.

However, IKT is not owned by the Government. Its owners are two associations which are again non-profit organizations of their own:

a) IKT-Association of Network Operators:
Members are more than 130 cities, among them Berlin, Hamburg, Cologne and London (Thames Water). They hold together 66.6% of IKT.

b) IKT-Association of Industry and Service:
Members are more than 70 companies. They hold together 33.3% of IKT.

You can find information on projects and services at:
www.ikt-online.org

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