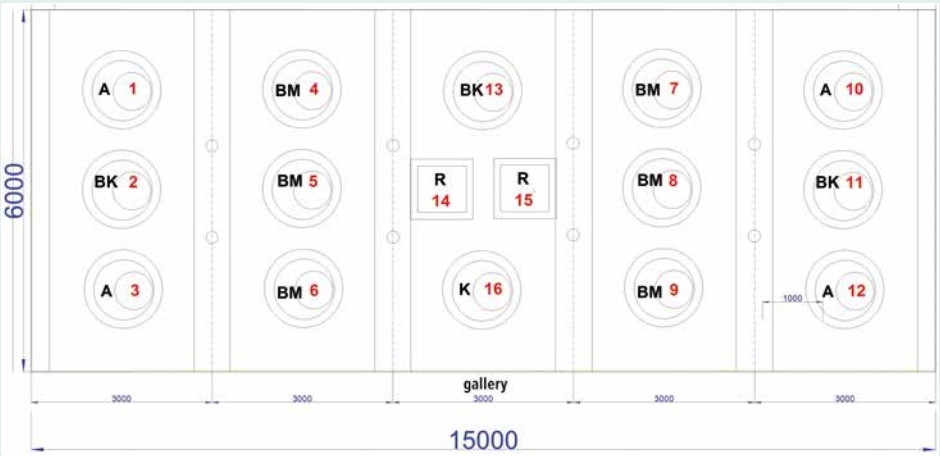
Coatings for a water-tight manhole shaft

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

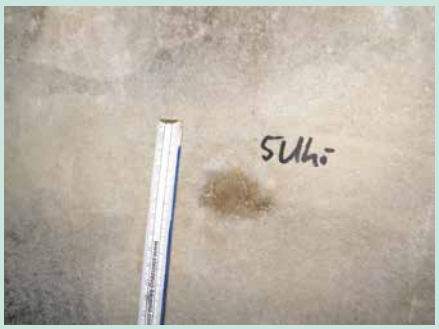
None of the methods exhibited any abnormalities after the short-term and long-term groundwater exposure resulting from the „isolated damage" scenarios. All of the 96 points of damage across the rehabilitated manholes were watertight (100 %). This damage scenario clearly presented no problem to the rehabilitation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

Dipl.-Ing. (FH) Serdar Ulutaş, MBA,
Prof. Dr.-Ing. habil. Bert Bosseler
Dipl.-Ök. Roland W. Waniek
Henning Winter
IKT – Institute for Underground Infrastructure

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

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- 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.
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

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.

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IKT – Institute for Underground Infrastructure

Exterbruch 1
45886 Gelsenkirchen
Germany

phone: +49 209 178060
fax: +49 209 17806-88
email: info@ikt.de

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